

GROUNDWATER FEASIBILITY STUDY

Moses Lake Wellfield Contamination Superfund Site

Moses Lake, Washington

DRAFT FINAL

April 2007



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**GROUNDWATER FEASIBILITY STUDY
MOSES LAKE WELLFIELD CONTAMINATION
SUPERFUND SITE
MOSES LAKE, WASHINGTON**

April 2007

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U.S. Environmental Protection Agency

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DISCLAIMER

This Groundwater Feasibility Study is a technical document. Any statements in the Groundwater Feasibility Study referring to activities that released, or could have released, trichloroethene or other compounds to the environment are not intended to define a responsible party or parties. Therefore, no responsibilities should be inferred based on the information included in this document.

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GLOSSARY

GLOSSARY OF ACRONYMS, ABBREVIATIONS, AND TERMS

ACRONYMS AND ABBREVIATIONS

µg	microgram; as normalized to liter (L) or kilogram (kg), the units equal parts per billion
ac	acre(s)
AOPC	area of potential concern
ARAR	applicable or relevant and appropriate requirements
AW	alluvial well
BBCC	Big Bend Community College
bgs	below ground surface
BW	basalt well with targeted screen interval set within the Priest Rapids and/or Roza 1 flow
C ₂ HCl ₃	1,1,2-trichloroethene (abbreviated in this FS to TCE)
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm/s	centimeters per second
CML	City of Moses Lake, Washington
COC	chemical of concern
COPC	chemical of potential concern
cPAH	carcinogenic polyaromatic hydrocarbon
CSM	Conceptual Site Model
CW	basalt wells with targeted screen interval set within the Roza 2 flow
Data Analysis	Site-Wide Groundwater Data Analysis
DBCP	b2-dibromo-3-chloropropane
DCE	dichloroethene
DNAPL	denser-than-water, non-aqueous phase liquid
DOD	Department of Defense
Ecology	Washington State Department of Ecology
EPA, USEPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment

ACRONYMS AND ABBREVIATIONS (CONT.)

FS	feasibility study
ft	foot/feet
FTZ	Foreign Trade Zone
FUDS	Formerly Used Defense Site
GAC	granular activated charcoal
GCEDC	Grant County Economic Development Council
GCIA	Grant County International Airport
gpd	gallons per day
GRA	general response action
GWFS	Groundwater Feasibility Study
HI	hazard index
HQ	hazard quotient
IAG	Interagency Agreement
IC	Institutional control
IRA	Interim Removal Action
ISCT	in-situ chemical treatment
kg	kilogram(s)
L	liter(s)
LAFB	Larson Air Force Base
LMWTP	Larson Municipal Waste Treatment Plant
LNAPL	lighter-than-water, non-aqueous phase liquid
LOX	liquid oxygen
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MDL	method detection limit
mg	milligram(s)
MP	Main Plume
MRL	method reporting limit
MTBE	methyl tertiary butyl ether
MTCA	Model Toxics Control Act
MWH	MWH Global, Inc. (from merger of Montgomery-Watson, Inc. and Harza Engineering Co.)
NaMnO_4	sodium permanganate

ACRONYMS AND ABBREVIATIONS (CONT.)

NAPL	non-aqueous phase liquid
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEI	Nature and Extent Investigation
NEP	northeast plume
NPL	National Priorities List
O&M	operation and maintenance
NRC	National Research Council
NWTPH-HCID	Northwest Total Petroleum Hydrocarbon Identification
OSWER	Office of Solid Waste and Emergency Response
PAH	polyaromatic hydrocarbon
ppbv	parts per billion by volume
pH	potential hydrogen
PQL	practical quantitation limit
PRAG	preliminary remedial action goal (proposed for this Site)
PRG	preliminary remediation goal (a generic list maintained by USEPA)
PRP	potentially responsible party
PSA	potential source area
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
REPDL	reporting limit
RI	Remedial Investigation
RI/BRA	Remedial Investigation and Baseline Risk Assessment
ROD	Record of Decision
SDWA	[Federal] Safe Drinking Water Act
SIM	selective ion monitoring
SSFS	Shallow Soils Feasibility Study
T-BACT	The Best Available Control Technology for Toxics
TBC	to be considered
TCE	trichloroethene (also cited in other documents as trichloroethylene)
Site	Moses Lake Wellfield Contamination Superfund Site
TM	Technical Memorandum
TPH-Gx	total petroleum hydrocarbons gasoline extended analysis

ACRONYMS AND ABBREVIATIONS (CONT.)

TPH-Dx	total petroleum hydrocarbons diesel extended analysis
U.S.C.	United States Code
UGA	Urban Growth Area
USACE	U.S. Army Corps of Engineers
USAF	United States Air Force
VOC	volatile organic compound
WAC	Washington Administrative Code
WWTP	wastewater treatment plant
ZVI	zero-valent iron

DEFINITION OF TERMS

a-basalt	The shallowest interval of the Wanapum Basalt, which consists of weathered, porous and fractured basalt.
Alluvium	A general term for clay, silt, sand and gravel or similar unconsolidated material that was deposited during relatively recent geologic time by a stream or other body of running water.
Aquifer test	A test that induces changes in water levels in a well (by pumping, for example) and includes measurement of resulting changes in water level as the aquifer responds to the induced changes.
Aphyric	A textural term for volcanic rocks meaning without phenocrysts.
Aquitard	A geologic unit that retards, but does not prevent, the flow of water to or from an adjacent aquifer. It does not readily yield water to wells or springs but may serve as a storage unit for groundwater.
b-basalt	The second interval within the Wanapum Basalt, which is characterized by a fine grained, dark gray basalt with minor fracturing and vesicular zones.
Breccia	A coarse-grained rock composed of angular, broken rock fragments held together by a mineral cement or a fine-grained matrix.
Brecciation	Formation of a breccia.
Caliche	A reddish-brown to buff or white calcareous material of secondary accumulation, commonly found in layers on or near the surface of soils in arid and semiarid regions.
Clastics	Fragments of rocks that have moved from their place of origin.
Colonnade	In volcanic rocks (basalt), the lower zone that typically has well formed columns.
Columbia River Basalt Group	Miocene basalts of central and southern Washington, northern Oregon, and western Idaho. Consists of over 300 individual flows.
Conceptual Site Model	A diagram that identifies the pathways and exposure routes between sources of contamination and living organisms.
Conceptual Hydrogeologic Model	A model that describes the hydrostratigraphy, structural and hydraulic features of the subsurface materials at a site.

DEFINITION OF TERMS (CONT.)

Conductivity (Hydraulic)	A coefficient of proportionality describing the rate at which water can move through a permeable medium.
Contact	A surface separating two types or ages of rock.
Contaminant transport modeling	A model that describes the fate and transport processes associated with movement of a contaminant in the environment.
Entablature	In volcanic rocks (basalt), the upper zone that is more intensely and randomly jointed than the lower zone, or colonnade.
Escarpment	A continuous cliff or relatively steep slope facing in one general direction, breaking the continuity of the land by separating two levels or gently sloping surfaces, and produced by erosion or faulting. The cliff between Cascade Valley and the Skyline district is a good example of an escarpment.
Ferrous Iron	Iron that exists in the reduced (+2) valence state.
Fluvial	Of or pertaining to a river or rivers
Formation	A formal body of rock identified by rock type characteristics and vertical position within the total series of rock.
Glacial Lake Missoula	An ancient lake formed during the last period of glaciation, about 10,000 years ago, that catastrophically drained during Pleistocene times creating the scabland topography evident in much of eastern Washington.
Head	Water level elevation in a well.
Hydraulic gradient	The change in total head with a change in distance in the direction that yields the maximum rate of change in head.
Hydrostratigraphic units	Geologic units with similar hydraulic properties are grouped into hydrostratigraphic units to develop a conceptual hydrogeologic model.
Interbed	A thin bed of material separating thicker beds of differing material.
Interfluve	The area between rivers, especially the relatively uneroded upland or ridge between two river valleys containing streams flowing in the same general direction.

DEFINITION OF TERMS (CONT.)

Isopach	A contour line drawn on a map through points of true thickness of a designated stratigraphic unit or group of stratigraphic units.
Low-flow sampling	A method of sampling that induces laminar (nonturbulent) flow in the immediate vicinity of the sampling pump intake, thus drawing fresh groundwater directly from the aquifer and minimizing disturbance in the well and in the aquifer.
Major ions	The chemical components that describe the largest fraction of the dissolved solutes (i.e., calcium, sodium, bicarbonate, sulfate, potassium, and chloride).
Method Detection Limit	The minimum concentration of a substance that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte (40 Code of Federal Regulations 136 Appendix B).
Method Reporting Limit	A data value specified by the client based on sensitivity requirements from project specific action levels. When an analyte is detected between the Practical Quantitation Limit and the Method Detection Limit, the data shall be flagged with a "J." The value reported is an estimation.
Olivine	A common rock-forming mineral that is typically light green in color.
Outburst Flood	(See Proglacial Flood).
Outcrop	That part of a geologic formation or structure that appears at the surface of the earth; also, bedrock that is covered only by thin surficial deposits such as Pleistocene sediments.
Paleochannel	An ancient channel (river valley).
Phenocryst	Relatively large conspicuous crystals in a porphyritic rock.
Phyric	A textural term for volcanic rocks meaning to contain phenocrysts.
Pinch-out	The gradual thinning of a geologic unit to the point of absence along a lateral boundary.
Plagioclase	A common rock-forming mineral that consists of numerous subspecies and is typically whitish-gray or gray.

DEFINITION OF TERMS (CONT.)

Pleistocene	A segment of geologic time that began 1.6 million years ago and lasted until the start of the Holocene some 8,000 years ago. The Pleistocene is an epoch within the Quaternary Period.
Pleistocene sediments	Sediments deposited during the Pleistocene. At the Site, they represent the uppermost stratigraphic unit encountered in the study area, which consisted of unconsolidated sand to boulder-sized material. Includes the Ringold and Hanford Formations.
Pliocene	A segment of geologic time that began 5.3 million years ago and lasted until the start of the Pleistocene some 1.6 million years ago. The Pliocene is the last epoch within the Tertiary Period.
Plunge	The inclination of a fold axis or other linear geologic feature.
Porphyritic	Said of the texture of an igneous rock that consists of larger crystals (phenocrysts) set in a finer grained groundmass, which may be crystalline or glassy or both.
Potentiometric surface maps	A contour map of the surface that represents the level to which water will rise in tightly cased wells. The water table is the particular potentiometric surface for an unconfined aquifer.
Practical Quantitation Limit	The minimum levels, concentrations, or quantities of a target variable (e.g., target analyte) that can be reported with a specified degree of confidence. For Department of Defense, the lowest standard of the calibration establishes the Practical Quantitation Limit, but it must be greater than or equal to 3 times the Method Detection Limit.
Priest Rapids Member	The upper member of the Wanapum Basalt present within the study area.
Proglacial flooding	Flooding caused by failure of a glacial ice dam, which contained a lake, e.g., Glacial Lake Missoula.
Quaternary	A geologic period of time consisting of the Pleistocene and Holocene epochs. It began 1.6 million years ago and extends up to the present time.
Quincy Basin	One of a series of basins that formed during development of the Columbia Plateau.
Roza Member	The member of the Wanapum Basalt beneath the Priest Rapids

DEFINITION OF TERMS (CONT.)

Ringold Formation	Plio-pleistocene sediments consisting of medium sand to clay with some caliche. These sediments underlie Hanford Formation over most of the study area.
Scabland	An elevated area underlain by flat-lying basalt flows with a thin soil cover and sparse vegetation and usually with deep, dry channels scoured into the surface.
Semiconfined	Said of an aquifer in which leakage occurs through the overlying aquitard.
Syncline	A fold of which the core contains the younger rocks and is generally concave upward.
Vesicular	Containing small cavities formed by gas bubbles in cooling lava.
Wanapum Basalt Formation	The Miocene basalt formation is part of the Columbia River Basalt Group located above the Vantage Member and below the Saddle Mountains Basalt.
Water table	The surface in an unconfined aquifer or confining bed at which the pore pressure is atmospheric. It can be measured by installing a shallow well extending a few feet into the zone of saturation and measuring the water level in the well.
Well completion logs	A diagram that is used to describe the rock types encountered and the construction details of a well.

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

This Groundwater Feasibility Study (GWFS) is one of two feasibility studies (FS) for the Moses Lake Wellfield Contamination Superfund Site (Site). The GWFS provides the preliminary regulatory and technical considerations used to evaluate contaminants in groundwater at the Site. The second document, the Shallow Soils Feasibility Study (SSFS) addresses Site soils to 15 feet (ft) of depth below ground surface (bgs) (U.S. Army Corps of Engineers [USACE, 2005]). Together, the FSs for the Site present the alternatives ranked as most favorable that achieve compliance with statutory requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA – 42 United States Code [U.S.C.], Section 9601 et seq.) and regulatory requirements of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP – 40 Code of Federal Regulations [CFR], Section 300).

In 1988, analytical results from groundwater samples collected by the Washington State Department of Social Health Services from eight wells serving the City of Moses Lake, Washington, municipal water supply system indicated that three of the wells contained concentrations of trichloroethene (C_2HCl_3 , abbreviated in this FS to TCE). The concentration exceeded the U.S. Environmental Protection Agency's (USEPA's) primary drinking water standard, or maximum contaminant level (MCL) of 5 micrograms per liter ($\mu g/L$). A private water purveyor, Skyline Water System, Inc., had two wells in which TCE was also discovered.

USACE, on behalf of the Department of Defense (DOD), responded to environmental contamination discovered at Formerly Used Defense Sites, sites such as the former Larson Air Force Base (LAFB). In 1989, USACE began its process of project documentation and approval of action called the Inventory Project Report, which determines the level of initial action to be taken by USACE. In 1991, both a Phase I Remedial Investigation (RI) and a Potentially Responsible Party (PRP) investigation were initiated by USACE. The Phase I RI at the former LAFB included a preliminary evaluation of the extent of TCE contamination in the uppermost aquifers and investigation of four potential source areas for TCE, tetraethyl lead, and radionuclides. Field investigations were conducted between August 1991 and October 1992. The results of the Phase I RI, released in two reports (Dames and Moore, 1993; Dames and Moore, 1995), indicated that TCE was consistently present in alluvial and upper basalt groundwater in a limited central area of the former base. The boundary of the TCE plume was partially defined to the north and east, but the south and west boundaries were not clearly delineated.

In 1992, the Site was listed on the Washington State Department of Ecology's (Ecology) *Confirmed and Suspected Sites Report* as a confirmed drinking water and groundwater hazardous substance site, with halogenated organic compound contamination. On the Ecology list, the Site is listed as "Moses Lk WF."

On October 14, 1992, the USEPA termed the affected areas of the former LAFB and areas that are downgradient in terms of groundwater flow as the "Moses Lake Wellfield Contamination Superfund Site," and listed it on the CERCLA *National Priorities List (NPL) for Uncontrolled*

Hazardous Waste Sites. The Site consisted of potential source areas in the former LAFB and the TCE-contaminated groundwater plume.

In 1994, Region 10 USEPA issued a report that identified PRPs in the Site (USEPA, 1994). This document included historical source materials, title documents, corporate records, CERCLA 104(e) responses, and interviews with individuals. Executive Order 12580 requires the DOD to enter into Interagency Agreements (IAGs) or Federal Facility Agreements at NPL and non-NPL sites, wherever practical, with Federal, State, and local entities for execution of RI/FS and remedial actions. The Executive Order also identifies DOD as the lead response agency at its own facilities.

In 1999, USEPA and USACE, on behalf of the DOD, entered into an IAG to establish authority for the RI/FS of the Site. USEPA signed the IAG on February 11, 1999, and USACE signed it on March 2, 1999. USEPA Headquarters delegated authority to the USEPA Regional Administrator, which was in turn delegated to USEPA Region 10 Director of the Office of Environmental Cleanup and the USEPA Region 10 Associate Director of the Office of Environmental Cleanup.

The IAG stipulated that a RI/FS would be undertaken. The FS would determine and evaluate alternatives for remedial actions to prevent, mitigate, abate, or otherwise respond to or remedy any release or threatened release of hazardous substances, pollutants, or contaminants at or from the Site in accordance with CERCLA.

This GWFS describes results from the subsequent Remedial Investigation/Baseline Risk Assessment (MWH Global Inc. [MWH], 2003a), the *Final Supplemental Remedial Investigation Report* (MWH, 2004a), and Appendix A, *Nature and Extent Investigation (NEI)*. The GWFS presents and updates a Conceptual Site Model (CSM) describing Site hydrology; groundwater contaminant distribution of the principal contaminant, TCE; fate and transport; exposure routes; and consequences in terms of human health and ecological risk and compliance with environmental laws. Based on a review of information for the Site, two compounds – TCE (Site wide) and acetone (limited essentially to one well) – are identified as contaminants of concern. TCE is used to delineate the contamination.

Two areas of potential concern (AOPC) for groundwater are identified in two basalt aquifers: the Priest Rapids-Roza 1 aquifer and the Roza 2 aquifer¹. The Federal/State MCL of 5 µg/L for TCE in groundwater was used to map the AOPCs. The AOPCs are described below, and are illustrated in figure 2.2-1. The AOPCs represent the best knowledge at the time of writing the GWFS. Additional information may change their shape and extent. AOPCs are map projections and can be visualized as extending from ground surface down to a depth corresponding (at least) to the dense flow interior of the Roza 2 basalt aquifer. However, within the AOPCs' limits, not

¹ A third area, AOPC 3, was initially defined based on contamination detected at several locations (99-BW16, 04-BW04, and 04-BW05) in the Roza 1 aquifer (Priest Rapids formation pinches out in this area) with relatively limited extent south of the airport terminal. The Roza 2 aquifer has indications of TCE beneath this area; however, concentrations of TCE in both aquifers appear to be below the PRAG, with one exception at well 04-BW05, which was slightly above the PRAG (6.06 µg/L). The alluvial aquifer in this area is restricted to the Ringold and TCE concentrations do not exceed the MCL. This AOPC was not retained for evaluation as recent concentrations have been below the PRAG.

all groundwater encountered is necessarily contaminated. For example, in nearly all instances, alluvial groundwater is believed to be free of contamination exceeding the TCE MCL inside the AOPCs.

AOPC 1's areal extent is based on TCE contamination above the MCL of 5 µg/L in the upper basalt aquifer, Priest Rapids-Roza 1. The estimated extent of the contaminated groundwater exceeding the PRAG in AOPC 1 is 0.6 square miles. AOPC 1 extends from Site 20 (South Base Dump) south-southwest to the Skyline area. The Roza 2 aquifer has been demonstrated to be contaminated above the MCL within the Priest Rapids-Roza 1 area, and is estimated to have the same areal extent with proportionally less TCE contamination than Priest Rapids-Roza 1. Concentrations within the Priest Rapids-Roza 1 aquifer range up to at least 88 µg/L, whereas Roza 2 concentrations range up to 30 µg/L. Portions of the overlying alluvial aquifer (the Hanford and Ringold Formations) have shown TCE below the MCL.

AOPC 2's areal extent is based on TCE contamination above the MCL of 5 µg/L in the upper basalt aquifer, Priest Rapids-Roza 1. AOPC 2 extends across an area (0.5 square miles) encompassing several former landfills near the southern end of the southeast runway to the south-southwest and a smaller area approximately 1,300 ft to the east. These areas of TCE greater than 5 µg/L are considered to be within the same AOPC, because the estimated area of TCE greater than 0.5 µg/L incorporates both treatment areas (figure 2.2-1).

The larger of the two areas is designated "*Main Plume (MP)*" and covers the groundwater in the Priest Rapids-Roza 1 and Roza 2 beneath former landfills. TCE concentrations within AOPC 2 Priest Rapids-Roza 1 MP range from 5 to 41 µg/L. The northwest portion of the plume starts near the end of the southeast runway and extends approximately 6,000 ft south-southwest. In this area, the extent of the Roza 2 plume is based upon analogy to the Priest Rapids-Roza 1 plume, because it is based upon only one well with TCE concentrations ranging from 21 to 24 µg/L. Concentrations within the Hanford and Ringold formations are apparently less than 5 µg/L within this AOPC.

The smaller area to the east, designated "*Northeast Plume (NEP)*," is defined by TCE contamination found in a cluster of wells somewhat remote from potential shallow soils source areas and extends 2,500 ft in a south-southwest direction from approximately 500 ft southwest of Site 21 (the Larson Municipal Wastewater Treatment Plant). TCE concentrations in the Priest Rapids-Roza 1 in this area range from 5 to 14 µg/L. Extent or existence of Roza 2 TCE contamination is not known for this treatment area. TCE contamination greater than 0.5 µg/L is not known to exist within the alluvial aquifer in this area.

The NCP (40 CFR 300.430(a)(iii)(F)) states, "EPA expects to return usable ground waters to their beneficial uses wherever practicable, within a time-frame that is reasonable given the particular circumstances of the site. When restoration of ground water to beneficial use is not practical, EPA expects to prevent further migration of the plume, prevent exposure to the contaminated ground water, and evaluate further risk reduction."

Subsequent to defining the Site chemicals of concern (COCs) and impacted groundwater areas or AOPCs, preliminary legal requirements, called applicable or relevant and appropriate requirements (ARARs) and to be considered (TBC) guidance relating to defining and

accomplishing a prospective cleanup, are reviewed and evaluated for groundwater at the Site. Numerical cleanup standards, or PRAGs, are proposed for TCE and acetone. The PRAG for TCE is 5 µg/L based on the primary drinking water standard or Federal and State MCL. The PRAG for the limited-area acetone plume is 7.2 mg/L based upon calculations conducted in accordance with the Washington Model Toxics Control Act Method B. Narrative remedial action objectives (RAOs) for groundwater are developed to address legal requirements, and are proposed below for the Site.

- RAO 1. Prevent human exposure to contaminated groundwater.
- RAO 2. Minimize horizontal and vertical extents of groundwater contaminant plumes exceeding PRAGs.
- RAO 3. Prevent or minimize further migration of contaminants from source materials to groundwater.
- A combination of RAO 2 and RAO 3 represents the treatment of groundwater and/or source material so that the aquifer can be restored to its highest beneficial use in accordance with the NCP. Remedial alternatives are developed respective of TCE in groundwater; only continued monitoring is identified for the limited acetone-contamination subarea.

General response actions (GRAs) identified to achieve RAOs for the Site are: (1) No action (as required by CERCLA); (2) institutional controls (ICs); (3) other site controls (such as alternative clean water supplies); (4) containment; (5) ex-situ treatment; and (6) in-situ treatment. Technologies and process options are identified to define GRAs. For actions involving shallow surface soils, refer to the SSFS. For deep unsaturated soils, no primary sources have been identified. The most effective, implementable, and cost-effective administrative and technical process options are described as assemblies prior to being combined into alternatives.

- Assembly 1. Actions to prevent exposure of the public to contaminated groundwater.
 - IC options.
 - Alternate water supplies.
 - Individual well treatment.
 - Physical barriers.
 - Groundwater monitoring.
- Assembly 2. Hydraulic containment to control migration of TCE in groundwater.
- Assembly 3. Ex-situ groundwater treatment methods.
- Assembly 4. In-situ groundwater treatment methods.

From these assemblies, the following alternatives for detailed analysis are proposed.

- Alternative I – No Action.
- Alternative II – Basic Action – Assembly 1. Assembly 1 elements are included in the

Basic Action alternative, and may be applied in various combinations to both AOPCs and to both the Priest Rapids-Roza 1 and Roza 2 aquifers therein. The alternative seeks to prevent public exposure to contaminated groundwater (i.e., RAO 1).

- Alternative III – Basic Action Plus Groundwater Extraction and Ex-Situ Treatment – Assemblies 1+3. This alternative prevents public exposure to contaminated groundwater and minimizes horizontal and vertical extents of groundwater contaminant plumes exceeding PRAGs, i.e., RAOs 1 and 2.
- Alternative IV – Basic Action Plus In-Situ Groundwater Treatment – Assemblies 1+4. This alternative prevents public exposure to contaminated groundwater and minimizes horizontal and vertical extents of groundwater contaminant plumes exceeding PRAGs, i.e., it addresses RAOs 1 and 2.

The alternatives are evaluated against the seven CERCLA criteria. These are the two pass/fail “threshold criteria” (protection of human health and the environment and compliance with ARARs and the five “balancing criteria” (short-term effectiveness; long-term effectiveness and permanence; reductions in toxicity, mobility, and volume through treatment; implementability; and cost). The alternatives are then scored and ranked for each treatment area.

Alternatives III and IV passed the **Protection of Human Health and the Environment** criterion. Alternative I (No Action) failed and Alternative II scored a “qualified pass” due to uncertainties associated with maintenance of ICs.

Regarding **Compliance with ARARs**, CERCLA requires returning aquifers to their beneficial use, which in this case is to return all Site groundwater to below the Safe Drinking Water Act MCL for TCE. Alternatives I and II likely would not meet the MCL at all points in the aquifer, because they do not seek to accomplish reduction in plume size. Alternatives III and IV may meet the requirement, because: (a) They would reduce the area of contaminated aquifer by treatment, (b) they would likely assure that contaminated areas are within surface land-use categories where public ownership and zoning may further aid in reducing exposure, and (c) they may also reduce the contribution of the source to the extent that the MCL would be met on cessation of treatment. Because the location of deep TCE sources in the aquifers remains unknown, although certain areas are more likely than others, statement, (c) above is acknowledged to be uncertain. It is not possible with current information to estimate a timeframe for its attainment.

Short-Term Effectiveness for an alternative refers to its effect on human health and the environment during implementation of the remedial action until RAOs are met. In this FS, the attainment of RAO 2 (minimize horizontal and vertical extents of groundwater contamination plumes exceeding PRAGs) is used as the main component to evaluate and compare short-term effectiveness. Alternative comparison for this balancing criterion is:

Alternative I	All Treatment Areas	<i>Poor, unfavorable</i>
Alternative II	All Treatment Areas	<i>Poor, unfavorable</i>
Alternative III	AOPC 1 Priest Rapids-Roza 1	<i>Good, generally favorable</i>
Alternative III	AOPC 1 Roza 2	<i>Good, generally favorable</i>
Alternative III	AOPC 2 Priest Rapids-Roza 1 (MP)	<i>Most favorable alternative</i>

Alternative III	AOPC 2 Priest Rapids-Roza 1 (NEP)	<i>Fair, potentially unfavorable</i>
Alternative III	AOPC 2 Roza 2	<i>Fair, potentially unfavorable</i>
Alternative IV	AOPC 1 Priest Rapids-Roza 1	<i>Good, generally favorable</i>
Alternative IV	AOPC 1 Roza 2	<i>Good, generally favorable</i>
Alternative IV	AOPC 2 Priest Rapids-Roza 1 (MP)	<i>Good, generally favorable</i>
Alternative IV	AOPC 2 Roza 2	<i>Good, generally favorable</i>

The **Long-Term Effectiveness and Permanence** criterion evaluates the ability of an alternative to prevent or minimize risk to public health and the environment after RAOs have been met. In this FS, long-term effectiveness and permanence addresses site conditions after the attainment of RAOs 1 and 2. In essence, it is unclear whether any alternative meets RAO 3, therefore, consideration of long-term effectiveness and permanence is qualified for what is possible at the Site. Alternative comparison for this balancing criterion is:

Alternative I	All Treatment Areas	<i>Poor, unfavorable</i>
Alternative II	All Treatment Areas	<i>Poor, unfavorable</i>
Alternative III	AOPC 1 Priest Rapids-Roza 1	<i>Fair, potentially unfavorable</i>
Alternative III	AOPC 1 Roza 2	<i>Fair, potentially unfavorable</i>
Alternative III	AOPC 2 Priest Rapids-Roza 1 (MP)	<i>Good, generally favorable</i>
Alternative III	AOPC 2 Priest Rapids-Roza 1 (NEP)	<i>Good, generally favorable</i>
Alternative III	AOPC 2 Roza 2	<i>Good, generally favorable</i>
Alternative IV	AOPC 1 Priest Rapids-Roza 1	<i>Most favorable alternative</i>
Alternative IV	AOPC 1 Roza 2	<i>Fair, potentially unfavorable</i>
Alternative IV	AOPC 2 Priest Rapids-Roza 1 (MP)	<i>Good, generally favorable</i>
Alternative IV	AOPC 2 Priest Rapids-Roza 1 (NEP)	<i>Not Applicable (see text)</i>
Alternative IV	AOPC 2 Roza 2	<i>Good, generally favorable</i>

The **Reduction of Toxicity, Mobility, or Volume through Treatment** criterion addresses the CERCLA preference for selecting remedial actions that employ treatment technologies to permanently and significantly reduce toxicity, mobility, or volume of hazardous substances as their principal element. Alternative comparison for this balancing criterion is:

Alternative I	All Treatment Areas	<i>Poor, unfavorable</i>
Alternative II	All Treatment Areas	<i>Poor, unfavorable</i>
Alternative III	AOPC 1 Priest Rapids-Roza 1	<i>Good, generally favorable</i>
Alternative III	AOPC 1 Roza 2	<i>Good, generally favorable</i>
Alternative III	AOPC 2 Priest Rapids-Roza 1 (MP)	<i>Good, generally favorable</i>
Alternative III	AOPC 2 Priest Rapids-Roza 1 (NEP)	<i>Good, generally favorable</i>
Alternative III	AOPC 2 Roza 2	<i>Good, generally favorable</i>
Alternative IV	AOPC 1 Priest Rapids-Roza 1	<i>Most favorable alternative</i>
Alternative IV	AOPC 1 Roza 2	<i>Most favorable alternative</i>
Alternative IV	AOPC 2 Priest Rapids-Roza 1 (MP)	<i>Good, generally favorable</i>
Alternative IV	AOPC 2 Priest Rapids-Roza 1 (NEP)	<i>Not Applicable (see text)</i>
Alternative IV	AOPC 2 Roza 2	<i>Good, generally favorable</i>

Implementability is used as a measure of both the technical and administrative feasibility of constructing, operating, and maintaining a remedial action alternative. Alternative comparison for this balancing criterion is:

Alternative I	All Treatment Areas	<i>Good, generally favorable</i>
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Alternative II	All Treatment Areas	<i>Good, generally favorable</i>
Alternative III	AOPC 1 Priest Rapids-Roza 1	<i>Good, generally favorable</i>
Alternative III	AOPC 1 Roza 2	<i>Good, generally favorable</i>
Alternative III	AOPC 2 Priest Rapids-Roza 1 (MP)	<i>Good, generally favorable</i>
Alternative III	AOPC 2 Priest Rapids-Roza 1 (NEP)	<i>Good, generally favorable</i>
Alternative III	AOPC 2 Roza 2	<i>Good, generally favorable</i>
Alternative IV	AOPC 1 Priest Rapids-Roza 1	<i>Good, generally favorable</i>
Alternative IV	AOPC 1 Roza 2	<i>Fair, potentially unfavorable</i>
Alternative IV	AOPC 2 Priest Rapids-Roza 1 (MP)	<i>Fair, potentially unfavorable</i>
Alternative IV	AOPC 2 Priest Rapids-Roza 1 (NEP)	<i>Not Applicable (see text)</i>
Alternative IV	AOPC 2 Roza 2	<i>Fair, potentially unfavorable</i>

Cost considers both capital and operation and maintenance (O&M) costs for each alternative at each treatment area. Periodic costs associated with the administration and remedial action operation were calculated separately from the O&M costs. Cost is mainly used to eliminate alternatives that are significantly more expensive than others without proportional benefits or to choose among several alternatives offering similar protection to human health and the environment. Alternative IV was the most costly alternative, and the assumed advantage of incidental treatment of an unfound source requires tradeoff with its greater cost.

Alternative I	All Treatment Areas	<i>Most favorable alternative</i>
Alternative II	All Treatment Areas	<i>Good, generally favorable</i>
Alternative III	AOPC 1 Priest Rapids-Roza 1	<i>Good, generally favorable</i>
Alternative III	AOPC 1 Roza 2	<i>Good, generally favorable</i>
Alternative III	AOPC 2 Priest Rapids-Roza 1 (MP)	<i>Good, generally favorable</i>
Alternative III	AOPC 2 Priest Rapids-Roza 1 (NEP)	<i>Good, generally favorable</i>
Alternative III	AOPC 2 Roza 2	<i>Good, generally favorable</i>
Alternative IV	AOPC 1 Priest Rapids-Roza 1	<i>Fair, potentially unfavorable</i>
Alternative IV	AOPC 1 Roza 2	<i>Fair, potentially unfavorable</i>
Alternative IV	AOPC 2 Priest Rapids-Roza 1 (MP)	<i>Poor, unfavorable</i>
Alternative IV	AOPC 2 Priest Rapids-Roza 1 (NEP)	<i>Not Applicable (see text)</i>
Alternative IV	AOPC 2 Roza 2	<i>Poor, unfavorable</i>

The alternatives and assemblies ranked as “most favorable” from the detailed analysis of alternatives are shown below. (Note: Bolding indicates the immediate or primary actions.)

Area	Most Favorable Primary Action	Contingent Action	Estimated Present Value
All AOPCs	Alternative II	N/A	\$ 7,900,000
AOPC 1 Priest Rapids-Roza 1	Assembly 4 (Ex-situ)	Assembly 3 (In-situ)	\$ 6,300,000
AOPC 1 Roza 2	No immediate action	Assembly 3 (In-situ)	\$ 2,000,000
AOPC 2 Priest Rapids-Roza 1 MP	Assembly 3 (In-situ)	N/A	\$ 3,200,000
AOPC 2 Priest Rapids-Roza 1 NEP	No immediate action	Assembly 3 (In-situ)	\$ 2,000,000
<u>AOPC 2 Roza 2</u>	<u>No immediate action</u>	<u>N/A</u>	<u>\$ 2,100,000</u>
Primary Total			\$ 17,400,000
Total with Contingency			\$ 23,500,000

CHAPTER 1
Introduction and
Site Description

CHAPTER 1. INTRODUCTION AND SITE DESCRIPTION

1.0 INTRODUCTION

1.0.1 Purpose and Feasibility Study (FS) Process

This Groundwater Feasibility Study (GWFS) for the Moses Lake Wellfield Contamination Superfund Site (Site), Moses Lake, Washington, was prepared by the U.S. Army Corps of Engineers, Seattle District (USACE), under the Formerly Used Defense Sites program of the Defense Environmental Restoration Act. The Site location is shown in figure 1.0-1. The Site is listed on the National Priorities List (NPL). Preparation of this document occurred under an Interagency Agreement (IAG) with the U.S. Environmental Protection Agency (USEPA), the lead regulatory agency. The GWFS provides the preliminary regulatory basis and technical considerations used in the evaluation of potential remedial alternatives. The alternatives address contaminant sources and patterns of contamination in groundwater at the Site. There is a parallel FS for the shallow surface soils of the Site, called the Shallow Soils Feasibility Study (SSFS) described below.

The GWFS is prepared in accordance with statutory requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA – 42 United States Code [U.S.C.], Section 9601 et seq.), as amended by the Superfund Amendments and Reauthorization Act, as well as regulatory requirements of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP – 40 Code of Federal Regulations [CFR], Section 300).

A *Remedial Investigation and Baseline Risk Assessment Report* (RI/BRA) (MWH, 2003) was completed for the Site in 2003. It was amended by the *Final Supplemental Remedial Investigation Report* (MWH, 2004a). At the completion of the Final RI/BRA report, USACE and USEPA agreed that critical data gaps remained regarding the extent of groundwater contamination by trichloroethene (C₂HCl₃, abbreviated in this FS to TCE). Accordingly, USACE performed a Nature and Extent Investigation (NEI) (appendix A). Key data evaluations have been included in the GWFS text as appropriate.

This GWFS is a technical document. Any statements in the GWFS referring to activities that released, or could have released, TCE or other compounds to the environment are not intended to define a responsible party or parties. Therefore, no responsibilities should be inferred based upon the information included in this document.

In accordance with CERCLA, during the FS stage of the RI/FS process, site contamination is defined and related to risks and legal requirements for remediation. Then, remedial action objectives (RAOs) are developed to specify constituents and media of concern, potential risks to human health and the environment, and preliminary remedial goals are proposed. In the final stage, remedial technologies are screened and candidate technologies are assembled into remedial alternatives for evaluation in accordance with seven of the nine CERCLA criteria.

(The other two criteria, State and community acceptance, are completed by receipt of comments during the Proposed Plan and USEPA's response in the Record of Decision [ROD].)

1.0.2 Relationship between Groundwater and SSFS

For administrative reasons, the USACE and USEPA agreed to prepare two parallel feasibility studies (FSs) for the Site, an SSFS and this GWFS. Superfund sites are often divided into operable units to make sites more manageable. Initially, soil and groundwater were considered to be different operable units, although USEPA does not envision this separation to be used in the future Proposed Plan and ROD. Soil and groundwater actions are likely to be integrated in the Proposed Plan and ROD as needed. The GWFS describes the activities and basis for the remediation of groundwater at the Site; the SSFS describes these same elements for surface soils. In some instances, soil remediation activities may be necessary in order to protect groundwater. In that case, the activity is described in the SSFS and referenced in the GWFS as it pertains to the groundwater remedial alternatives. Together, the SSFS and GWFS documents are the basis for remedy selection by USEPA subsequently in a single Proposed Plan and ROD.

Shallow soils are defined as soils to a depth of 15 feet (ft), in accordance with State of Washington guidance for risk assessment under the Washington Model Toxics Control Act (MTCA), and as documented in responses to USEPA comments on the Exposure Assessment Technical Memorandum for the Human Health Risk Assessment (MWH, 2001). However, data collected from subsurface vadose-zone soils greater than 15 ft below ground surface (bgs) are discussed in the SSFS for information purposes (e.g., appendix A of the SSFS). At the direction of USEPA, contamination due to and including petroleum products was included in the RI/BRA and both FSs for the Site, even though petroleum products are typically outside the scope of CERCLA (these compounds are excluded from the list of CERCLA hazardous substances by the NCP). State regulations address petroleum products as subjects of environmental cleanup.

1.0.3 Organization of the GWFS

The GWFS is organized into four chapters and seven appendices, described below:

Chapter 1 – Introduction and Site Description. Chapter 1 describes the purpose, scope, and organization of the GWFS. It also describes the Site in terms of operational history, past administrative actions, site physical characteristics, nature, and extent of contamination, Conceptual Site Model (CSM) for fate and transport, and a summary of the human health and ecological risk assessments (ERAs).

Chapter 2 – RAOs, Regulatory Requirements, and Identification and Screening of Technologies. This chapter describes chemicals of concern (COCs) and lists RAOs. It accomplishes a legal analysis of preliminary applicable or relevant and appropriate requirements (ARARs) and to be considered (TBC) criteria that impact the selection of the remedial action. Using these FS requirements, chapter 2 develops preliminary remedial action goals (PRAGs) and general response actions (GRAs). It identifies volumes or areas of concern, and lists and screens technologies for each GRA. Finally, chapter 2 consists of the identification and evaluation of potentially applicable remedial technologies and process options.

Chapter 3 – Development and Identification of Remedial Alternatives for Detailed Analysis. This chapter combines technologies for the impacted medium into alternatives. It screens alternatives with respect to effectiveness, implementability, and cost and identifies alternatives to be taken into detailed analysis.

Chapter 4 – Detailed Analysis of Alternatives. Chapter 4 identifies potential remedial alternatives by area and evaluates them against seven of the nine CERCLA criteria: protection of human health and the environment; compliance with ARARs; long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability, and cost.

At USEPA's request, USACE compressed the preparation of the GWFS. In the 1998 Scope of Work for the Moses Lake Wellfield RI/FS, USACE agreed to provide the following three technical memoranda (TMs), as well as draft, draft final, and final FS reports.

- RAO TM.
- Remedial Technologies, Alternatives, and Screening TM.
- Comparative Analysis of Alternatives TM.

The RAO TM requirement was addressed by USEPA's review of a draft of chapter 2 of the GWFS; the Remedial Technologies, Alternatives, and Screening TM requirement was addressed by draft chapter 3; and the Comparative Analysis of Alternatives TM requirement was addressed by USEPA's review of draft chapter 4.

Chapter 5 – References. Lists the reference documents used in the development of this GWFS.

Appendices are as follows:

- Appendix A Nature and Extent Investigation.
- Appendix B Site-Wide Groundwater Data Analysis and Chemicals of Concern.
- Appendix C Evaluation of the Potential Shallow Soil Migration to Groundwater for Non-Volatile Organic and Inorganic Contaminants.
- Appendix D Evaluation of the Potential Shallow Soil Migration to Groundwater for Volatile Organic Contaminants.
- Appendix E Summary of Phase I RI/BRA and RI/BRA Results.
- Appendix F Cost Estimates and Design Details.
- Appendix G Historic TCE Results.

1.0.4 Specialized Language Used in the GWFS

The nature of the FS process is iterative and its terminology is specialized.

Terms relating to areas. As originally listed by USEPA, the Site did not have a particular limitation as to area and was intended to incorporate all areas effected by contamination in

groundwater or other media. Attempts were made to find *Potential Source Areas (PSAs)* within the undefined boundary called *study area* in the RI/BRA (MWH, 2003a), for evidence of releases of CERCLA hazardous substances. As the RI/BRA was developed and data acquired, the limits of groundwater contamination were refined, but no direct evidence of a shallow soil groundwater source area was discovered (this is described further in sections 1.5 and 1.6). Because no PSA was found to directly impact the groundwater, PSA refers to a vicinity (which may be defined by topography or based on historic activities) of a possible surface soil release. At the conclusion of the RI/BRA and the Supplemental Risk Assessment (MWH, 2004a), additional data were still needed to refine the extent of groundwater contamination. Accordingly, the NEI (appendix A) was conducted to provide further data.

Areas of potential concern (AOPCs) are described in GWFS chapter 1 as areas with elevated groundwater contaminant concentrations. An AOPC may refer to the extent of contamination in more than one aquifer under the areal (map) projection. Based on risk and statutory evaluations in the GWFS that define the cleanup levels, these AOPCs determine the areas of prospective remedial action. In this document, groundwater *treatment areas* are areas within an AOPC that receive the identified treatment technologies.

Terms relating to chemicals. In the early stages of the RI/BRA, a broad list of chemicals was considered, largely defined by the suspected or known activities associated with contaminant releases. Following screening of the long list against USEPA recommended values, the list was reduced for the sake of the Baseline Risk Assessment and Supplemental Risk Assessment to *Chemicals of Potential Concern (COPC)*, and contribution of both individual and co-occurring compounds to risk or hazard were documented. At the time of the GWFS, this COPC list is revisited to further reduce it to those compounds associated with risk above USEPA guidelines or exceeding ARARs. These compounds are called *COCs*. (This step occurs in chapter 2 of the GWFS.)

Terms relating to alternative development and evaluation. Beginning in chapter 2, actions to reduce exposure or groundwater treatment methodologies, called *potential technologies* with modifications called *process options* are evaluated for effectiveness, implementability, and preliminary cost to reduce the number considered to a smaller number of *assemblies* and subsequent alternatives. *Alternatives* are combined assemblies (technologies plus other actions) attuned to AOPC and aquifer-specific remedial needs. Alternatives are then subjected to detailed evaluation and comparison with one another in chapter 4, and comparative rankings are listed.

1.1 SITE HISTORY

1.1.1 Site Development History

The Grant County International Airport (GCIA) was initially developed in November 1942 as the Moses Lake Army Air Base to provide a temporary training center for B-17 pilots and crews. From March 1944 to September 1945, the base was used for the training of P-38 and P-39 pilots. At the end of 1945, the base was placed on caretaker status. Between 1945 and 1948, Boeing Corporation used the base to test B-47 and B-50 aircraft, and the base was reopened in November 1948 under the United States Air Force (USAF) Air Defense Command. In May 1950, it was renamed Larson Air Force Base (LAFB) and served as a Tactical Air Command

base from 1952, a Military Air Transport Service facility from 1957 and finally a Strategic Air Command base from 1960. The base provided numerous support facilities, including a hospital, barracks, fueling depots, hangars, schools, a wastewater disposal/treatment plant, and conventional weapons storage areas. In April 1952, the USAF started testing the Boeing B-52 at the base. The following year, an extensive building program was initiated, including a new 1,000-ft-deep well.

The construction of the Boeing Flight Center was initiated in 1954. Between 1954 and 1962, Boeing site operations included contract work for the USAF on the B-52 and KC-135 aircraft programs. Work on the B-52 program involved preparing aircraft for delivery, which included testing, maintaining, fueling, cleaning, painting, and, on occasion, stripping aircraft. From 1962 to 1963, Boeing's primary operations involved work on the B-52 fuel cell modification program, including metal fatigue testing.

In January 1960, Strategic Air Command assumed command of the base, moving crews and aircraft of the 327th Bombardment Squadron from Fairchild Air Force Base. Numerous structures were built, including additional flight operation facilities, housing, schools, waste and water systems, weapons storage and Titan I missile support facilities. Construction work on the Titan I missile support facilities was completed in March 1962, at which point the USACE Site Activation Task Force turned the facilities over to the USAF. In 1963, Boeing vacated its operations at LAFB.

On November 19, 1964, the Department of Defense (DOD) announced that the LAFB would be excess to its needs by June 30, 1966. On March 31, 1965, the 568th Strategic Missile Squadron was deactivated.

In 1966, the Grant County Port District No. 10 (also known as the Port of Moses Lake) acquired approximately \$25,000,000 worth of property and began operating the former base as the GCIA. The family housing area was sold to the Grant County Housing Authority. In 1965, the building that currently houses the Columbia Basin Job Corps Center was transferred from USAF ownership. Other non-operational land and buildings (dormitories, commercial and recreational facilities, and three hangars) were transferred to Big Bend Community College (BBCC). In 1968, Boeing resumed operations at the GCIA, purchasing approximately 130 acres (ac) at the Site, which included the present 3-Place Hangar. After purchase of the property, Boeing Commercial Airplane Company used the facility for tool storage. On January 1, 1985, custodianship of the facility was transferred to Boeing Military Airplane Company. At present, the Boeing facility includes the former USAF 3-Place Hangar and 3 additional acres. The Boeing facility is used for flight testing, crew training, airplane tool storage, and a proprietary nonproduction operation.

1.1.2 Regulatory History

In 1988, analytical results from groundwater samples collected by the Washington State Department of Social Health Services from eight wells serving the City of Moses Lake, Washington (CML), municipal water supply system indicated that three of the wells (ML-21, ML-22, and ML-28) contained concentrations of TCE exceeding the USEPA's primary drinking

water standard, or maximum contaminant level (MCL). A private water purveyor, Skyline Water System, Inc., had two wells in which TCE was also discovered.

USACE, on behalf of the DOD, responded to environmental contamination discovered at Formerly Used Defense Sites, sites such as the former LAFB. In 1989, USACE began its process of project documentation and approval of action called the Inventory Project Report, which determines the level of initial action to be taken by USACE. In 1991, both a Phase I RI and a Potentially Responsible Party (PRP) investigation were initiated by USACE. The Phase I RI at the former LAFB included a preliminary evaluation of the extent of TCE contamination in the uppermost aquifers, and four PSAs were investigated for TCE, tetraethyl lead and radionuclides. Field investigations were conducted between August 1991 and October 1992. The results of the Phase I RI, released in two reports (Dames and Moore, 1993; Dames and Moore, 1995), indicated that TCE was consistently present in alluvial and upper basalt groundwater in a limited central area of the former base. The boundary of the TCE plume was partially defined to the north and east, but the south and west boundaries were not clearly delineated.

In 1992, the Site was listed on the Washington State Department of Ecology's (Ecology) *Confirmed and Suspected Sites Report* as a confirmed drinking water and groundwater hazardous substance site, with halogenated organic compound contamination. On the Ecology list, the Site is listed as "Moses Lk WF."

On October 14, 1992, the USEPA termed the affected areas of the former LAFB and areas that are downgradient in terms of groundwater flow as the "Moses Lake Wellfield Contamination Superfund Site," and listed it on the CERCLA *NPL for Uncontrolled Hazardous Waste Sites*. The Site consisted of PSAs in the former LAFB and the TCE-contaminated groundwater plume.

In 1994, Region 10 USEPA issued a report that identified PRPs in the Site (USEPA, 1994). This document included historical source materials, title documents, corporate records, CERCLA 104(e) responses, and interviews with individuals. Executive Order 12580 requires the DOD to enter into IAGs or Federal Facility Agreements at NPL and non-NPL sites, wherever practical, with Federal, State, and local entities for execution of RI/FS and remedial actions. The Executive Order also identifies DOD as the lead response agency at its own facilities.

In 1999, USEPA and USACE, on behalf of the DOD, entered into an IAG to establish authority for the RI/FS of the Site. USEPA signed the IAG on February 11, 1999, and USACE signed it on March 2, 1999. USEPA Headquarters delegated authority to the USEPA Regional Administrator, which was in turn delegated to USEPA Region 10 Director of the Office of Environmental Cleanup and USEPA Region 10 Associate Director of the Office of Environmental Cleanup.

The IAG stipulated that an FS would determine and evaluate alternatives for remedial actions to prevent, mitigate, abate, or otherwise respond to or remedy any release or threatened release of hazardous substances, pollutants, or contaminants at or from the Site in accordance with CERCLA. The IAG stated that a RI/FS be conducted in accordance with CERCLA, the NCP, and USEPA guidance including the Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (Office of Solid Waste and Emergency

Response [OSWER] Directive 9355.3-01, 1988b) and Guidance for Data Usability in Risk Assessments (OSWER Directive 9285.7-05).

1.2 LAND, GROUNDWATER, AND SURFACE WATER USE

This section discusses land use in the Site area and nearby areas potentially impacted by site contamination.

1.2.1 Current Land Use

Current land use is variable and diverse in the Moses Lake area. Land use in the southern portion of and south of the Site consists of residential subdivisions, apartments, mobile home parks, commercial areas, and agricultural areas. The land in the northern portion of the Site is designated as commercial/industrial, with the majority of the land owned by the Port of Moses Lake. Land in the central portion of the Site is a mix of residential and commercial/industrial land use. In general, the areas north and east of the Site consist of unimproved open lands used for rural residences, agriculture, and rangeland; the western and southern edges of the Site are bounded by Moses Lake. Moses Lake is used for recreation and irrigation.

1.2.1.1 Port of Moses Lake District Property

Within the former air base that is now Port of Moses Lake District property, land use consists of aviation-related operations associated with the GCIA, and various aviations-related industries and businesses. The Port of Moses Lake owns approximately 4,667 ac contiguous to the airport property and near the airport. Within the Port of Moses Lake property, the first priority for land use is air operations. The second priority is for activities directly related to aviation such as rescue and fire fighting, fueling, aircraft maintenance and storage and terminal activities. The third priority is assigned to businesses that have some dependence upon air transport. The following categories designate the land uses for airport property according to the 1994 *Grant County Airport Master Plan* (Grant County, 1994a):

- Air Operations.
- Aviation Support.
- Aviation-Related Industrial.
- Aviation-Compatible Industrial.
- Commercial.
- Industrial.
- Open or Agricultural.

The GCIA has a main runway 13,500 ft long and is one of the largest airports in the United States. Existing airport facilities-related structures and systems include runways, taxiways, aprons, lighting systems, and navigational aids used for heavy jet training and testing by the Boeing Company, Japan Airlines, the U.S. Military, and other carriers (personal conversation between Albert Anderson, Port of Moses Lake, and Sheri Moore, USACE, on February 2, 2005).

Two runways at GCIA are designed for large aircraft and two runways are available for smaller aircraft. BBCC uses the latter for flight training. In addition to the runways, eight taxiways and six expansive apron areas are currently in operation. The Air Operations land use is defined primarily by runway orientations, dimensional criteria, and obstruction free areas. This area is reserved for airfield-related development such as runways, taxiways, aprons, and navigational aids; no other development is permitted. As shown on figure 1.2-1, rural remote, rural residential, or agricultural areas are situated on three sides of the GCIA. To the south and west, urban commercial/industrial and urban residential uses occur.

Aviation support areas include the airline terminal building and parking area, public safety building, fire fighting training area, hangars, fixed base operator, aviation fuel storage, and airfield maintenance. The main support area is located along the terminal apron.

Aviation-related industry includes fabrication, assembly, and activities that rely on aviation for the movement of products or people. Aviation-compatible industry includes industrial activities that do not interfere with aircraft operations. Excluded activities include manufacturing that emits smoke or electromagnetic radiation, attracts birds, or produces glare. Aviation-compatible industry requires highway or rail access and includes transport terminals, laboratories, warehouses, distribution centers, general manufacturing, parts assembly, and cold storage.

Industries on Port of Moses Lake property occur mainly in three developed areas: (1) An industrial park on the southeast edge of the airport; (2) a terminal and adjacent areas on the south edge of the airport; and (3) land adjacent to the airport to the east and northeast. The Port of Moses Lake leases approximately 820 ac of land. Approximately 580 ac are used for agriculture on land in the north portion of the airport. The Port of Moses Lake leases approximately 102 ac of land for irrigated agriculture along the center of the northwest edge of the Port of Moses Lake District property. Another large land lease is 100 ac to Inflation Systems, Inc.

As of January 2005, the five largest employers at the GCIA are as shown below (personal conversation, February 2, 2005, and Grant County Economic Development Council [GCEDC], 2004):

- Inflation Systems, Inc. (approximately 400 employees [GCEDC, 2004]).
- Genie Industries (approximately 200 employees).
- Nippon Chemi-Con (approximately 60 employees).
- Sonico, Inc. (approximately 40 – 50 employees).
- Japan Airlines (approximately 30 people).

Other major industries and operations continuing in the Port area include (Moses Lake Chamber of Commerce, 2004):

- Basic American Foods, since 1986.
- Rocket Research, now known as Primex, started in Moses Lake in 1979 and manufactures propellant and assembles a variety of products.

- Moses Lake Industries, operational in early 1985, is a subsidiary of Tama Chemical Co., Ltd., and produces an extremely pure chemical used as a photolithographic developer for integrated circuit diagrams.
- United States Forest Service signed a lease with the Port and is scheduled to construct a \$3,000,000 facility that will contain the latest pumping equipment and high speed loading machinery used to fight fires from the air.

Commercial use on Port property includes general office space and retail trade. The area on the northeast corner of State Route 17 and Chanute Street is a commercial use area. Examples of commercial activities include retail, food service, professional services, general office space, and a foreign trade zone (FTZ).

1.2.1.2 Unincorporated Areas

Unincorporated areas of Grant County bound the former LAFB. Figure 1.2-1 shows that areas zoned "Urban Commercial & Industrial" are present to the north, northeast, and south of the Port of Moses Lake district boundaries. Smaller industrial and commercial properties are also present south of the former LAFB boundaries and north of the city limits. Properties zoned "Agriculture" are located east and southeast of the Port of Moses Lake District and "Urban Commercial & Industrial" areas. Areas to the west of the Port and to the south or southwest of the lake are mainly considered "Rural Residential" or "Rural Remote."

Industries and businesses around Port property include education, aviation-related industries, general construction contractors, food and beverage-related industries, trucking, and agricultural supply industries. Many local and Federal Government agencies occupy facilities in the area near the Port, such as the Grant County Housing Authority, the National Guard, and the GCEDC.

Residential areas used for single-family residences and duplexes are located in the former LAFB housing complex, immediately south of the BBCC campus on the southwest edge of the Port of Moses Lake District boundaries. This residential area is bounded by State Route 17 on the west side and Patton Boulevard on the east. Additional residential areas (Skyline and Cascade Valley communities) are located south of the former LAFB housing area. The residential areas are intermixed with agricultural, public, and commercial properties. Residential areas are bounded by the CML to the south and extend to the west side of Moses Lake into Mae Valley.

Rural areas are characterized by low-density residential housing, concentrated mixed-use areas, isolated commercial and industrial uses, farms, forest, mining areas, and other open-space activities. Rural Remote lands are not suitable for intensive farming and are generally not attractive for residential development. The maximum density is one dwelling per 10 ac. Rural Remote land is located west of the northwest corner of the Port of Moses Lake District boundaries.

1.2.1.3 City of Moses Lake

Approximately 1 mile south of the south end of the Port of Moses Lake District boundary is the CML corporate boundary, shown in figure 2.2-1. The CML covers about 11.45 square miles. Based on a 1998 CML zoning map, land use areas south of vacant county land that is south of

the Port of Moses Lake District are zoned "Multi-Family Residential (R-3)" and "General Commercial and Business (C-2)." Further south and bordering State Route 17 are "Single Family" and "Two Family Residential" properties and "General Commercial and Business (C-2)." Properties south of Valley Road to the edge of Parker Horn are zoned "Single Family Residential (R-1)." In addition, two parcels of the former base, the Larson Waste Water Treatment Plant and the former firing range, have been incorporated into the CML.

1.2.2 Future Land Use

The Port of Moses Lake District area has 1,400 ac available for industry development inside the urban growth boundaries. The CML has designated Port property to be developed adjacent to the airport as "Industrial Light" and "Industrial Heavy." However, some areas west of the airport that are designated as "Industrial Light" currently lack utility connections.

Based on a population growth of approximately 11,000 additional people within the Urban Growth Area (UGA) between the years 2005 and 2018, land demand within the current city limits is anticipated to exceed the available supply. Therefore, other unincorporated land is likely to be incorporated into the city.

The Port of Moses Lake is the Federal Grantee of FTZ #203. In 1988, the Port of Moses Lake began application to become a FTZ. The FTZ is designed to eventually encompass 316 ac. The project is to be done in phases and could eventually include more than 10,000 square ft of buildings (Moses Lake Chamber of Commerce, 2004). The FTZ is designed to combine commerce park and airfreight-handling facilities to allow overseas goods to be shipped into the zone for future manufacturing, assembly, or storage, with no duty charged until the project is released for public consumption.

1.2.3 Groundwater Use

Groundwater is defined as water located within the subsurface of the earth that supplies, or is capable of supplying, water to wells and springs. Groundwater in the Moses Lake area is either located in alluvial sediments or in the porous or weathered portions of fractured bedrock. Groundwater is the major source of drinking water in Grant County. The groundwater is consumed treated or untreated depending on how the water is obtained, as well as used for irrigation, livestock watering, and manufacturing.

1.2.4 Surface Water Use

The Site and surrounding areas are bounded in three directions by surface waters: (1) Crab Creek to the east, (2) Lewis Horn and Parker Horn to the south and southeast, and (3) Moses Lake to the west and southwest. Moses Lake is made up of three main arms, which are over 18 miles long and up to 1 mile wide. It is the largest natural body of fresh water in Grant County. Moses Lake has over 120 miles of shoreline and covers 6,500 ac (Moses Lake Chamber of Commerce, 2004). Surface water use includes recreation in the Moses Lake area with over 247,000 ac of water on or near Moses Lake. Many local lakes (including Moses Lake) are open for year-round fishing. Local waters offer walleye, trout, bass, perch, crappie, catfish, and more (Moses Lake Chamber of Commerce, 2004).

Nonrecreational surface water use is dictated by the Columbia Basin Irrigation Project, which diverts water from the Columbia River below the Grand Coulee Dam through a series of irrigation canals and siphons. This water is distributed over approximately 70,000 ac for irrigation purposes over an area designated by the Washington Department of Natural Resources as agricultural. This area is not subdivided into drainage basins (Grant County, 2004b). Some of the water flows into Moses Lake and Potholes Reservoir by Rocky Coulee Waterway and Crab Creek.

Surface drainage is from north to south in the Site area. Other surface drainages in the area include a short intermittent stream west of the airport runways and several channels associated with agriculture in the eastern portion of the study area.

Water quality in Moses Lake is of concern to local residents as well as downstream users of Potholes Reservoir waters. In the past, the lake has had indications that it receives excessive nutrient loading of nitrogen and phosphorus. The principal nutrient source is irrigation return water via Crab Creek. Groundwater seeps, septic tank leachate, and recycling from bottom sediments add nutrients that result in floating algal mats during the summer recreation season (Grant County, 2004b).

1.3 DEMOGRAPHY

1.3.1 Moses Lake Area Demographics

Communities in the Moses Lake area continue to grow each year due to their well established agricultural economy, diversification of its agricultural industries, and expansion of nonagricultural and service industries. According to the GCEDC, the population of the CML has increased from 10,310 in 1970 to 11,235 in 1990 to 15,730 in 2003 (GCEDC, 2004). The population in the Moses Lake area was 27,650 in the year 2000. The communities in the Moses Lake area are relatively young with a projected 37.7 percent of the population under the age of 19 in the year 2005, based on the calculated growth rate and 35.2 percent under 19 years old in 2000. The average median annual income in 2000 for 25,207 households was \$35,276 (compared with \$50,182 for Washington State). The median home price in Grant County in 2003 was \$100,625, which compares with the Washington State median price of \$202,000.

1.3.2 Local Government

The CML Government is structured as a "City Manager/Council" municipality with seven elected officials. The Port of Moses Lake administration consists of a board of three commissioners and an executive manager. Grant County is governed by a board of three elected commissioners. The Grant County Public Health District provides critical programs and services for all people in Grant County, including review of groundwater programs. Washington Departments of Ecology and Health interact with the Public Health District and review aspects of groundwater quality, water supply, and well design and construction.

1.3.3 Local Water Systems

1.3.3.1 Water Supply System

According to the CML *Water System Plan for the Year 2000*, the CML is the largest potable water purveyor in Grant County (CML, 2001). Other small purveyors of water in the Moses Lake area, such as the Skyline Water System and the Cascade Valley Water District, serve small residential areas and mobile home parks. In addition to the large and small water providers, there are many private wells serving individual homes or small groups of homes in the Moses Lake area.

The entirety of the City's water supply is drawn from the Quincy Groundwater Subarea. The Quincy Groundwater Subarea is defined in Washington Administrative Code (WAC) 173-124-050 and includes the Moses Lake area. It was established to regulate shallow groundwater in a portion of the Columbia River Basin where water from the Columbia Basin Irrigation Project has recharged and significantly affected the shallow groundwater system. The city currently has 15 wells drawing from the Grand Ronde aquifer, the Wanapum aquifer, both Grand Ronde and Wanapum basalt aquifers, and 1 well drawing from the unconsolidated alluvial aquifer. Table 1.3-1 lists the City wells with their associated depths. (For a description of the aquifers in the area, see section 1.4.3.) The CML system's pumping capacity is 24.8 million gallons per day (gpd) with a peak demand of 16.4 million gpd (CML, 2001). Total usable storage for the city is 7.965 million gallons.

CML (2001) states that, in November 1999, there were 6,589 connections to the system serving approximately 18,300 people. Residential systems made up approximately 48.7 percent of total system usage (5,232 single family and 241 multi-family connections, including duplexes, apartments, and mobile home parks, with a calculated 2.7 persons per household). The current residential system is estimated to provide water to 14,800 out of 27,500 people in the area. Industrial/commercial/governmental connections made up 40.4 percent of the system with 1,116 connections. The cited plan shows that 10.9 percent of the water system usage was unaccounted for, due to possible leaks, faulty meters, and/or improper meter reading and recording.

A portion of the City's current water system includes this report's study area. The majority of the study area portion is made up of the water system of former LAFB and is designated the Larson Zone. According to the *Site Background Summary Report Moses Lake Wellfield Contamination Superfund Site* (MWH, 1999a), this zone serves approximately 5,000 people, and water from this zone has historically been obtained from a system of six deep wells (ML-21, -22, -23, -24, -28, and -29). Wells ML-21, 22, and 28 were rehabilitated by the city. However, after rehabilitation of ML-22, with the shallow basalt aquifers closed off within the well, the well did not produce sufficient water, and is no longer part of the CML water system. (The well was decommissioned in 1998, according to a water well report filed with the State on August 18, 1998.)

The city plan predicts that additional water rights and increases in sources and storage will have to be obtained in order to meet projected city growth. The predicted number of service connections in 2018 will be 11,554, which is almost double the current number of connections. The city has calculated that they will have sufficient water rights to meet user demands until the

year 2015. CML (2001) states that efforts are being made by the city to obtain adequate water rights to meet projected water service demands. The report does not indicate what portions of the increase will be accounted for by new well developments or new connections from existing facilities.

Based on the service maps within the cited plan, the existing city water service covers only a portion of the potential Moses Lake service area. The Urban Growth Boundary, referenced in this FS as the UGA, is shown on figure 2.2-1. The CML water system extensions are planned within the potential service area. Figure 1.3-1 shows the areas with current and future city water lines. Where (and when) city water lines are available, new users must meet the following conditions to connect to city water:

- The property must be within the city's corporate limits, be annexed into the city if its location permits it, or sign an annexation agreement.
- The potential user must extend the water system through the property to be served and pay any reimbursements due for previously installed improvements (see municipal code for further details).
- The potential user must pay any applicable water connection fees and system development charges.

In addition to city water, residence and businesses are served by small water purveyors within the UGA. Small water purveyor service areas are shown in figure 1.3-2. Some overlap in service areas exists between current city water service areas and small water purveyor areas, but the majority of small water purveyors provide water in areas where city water is not available. The small water purveyors serving the largest areas within the study area were the Skyline Water System, Cascade Valley Water District, Grant County Fairgrounds, and Basin Water (these systems are indicated on figure 1.3-2). As of 1999, approximately 77 households obtained their water from the Skyline water supply. In July 2003, USACE completed a replacement well for the Skyline Water Supply system, which had been contaminated with TCE.

Between 1999 and 2004, USACE sampled approximately 80 domestic wells with one or two connections developed in the study area. Some of these wells showed TCE contamination above the MCL. At these wells, USACE has installed engineering controls to prevent exposure to TCE contamination above the MCL. The maintenance of the engineering controls and the offering of residential water testing are presently conducted by USACE.

1.3.3.2 Sewer System

Two sewage treatment plants provide sanitation for the Moses Lake area, according to the Port of Moses Lake Web site. In the northeast area of the Site, the Larson Municipal Waste Treatment Plant (LMWTP) serves the former Larson Housing Area and the Port of Moses Lake. This system consists of shallow concrete pipes that collect and direct wastewater from the residential and commercial areas of the former LAFB to a lift station south of the Larson Wastewater Treatment Plant (WWTP) (MWH, 1999a). The other treatment plant in the area, the Sand Dunes Treatment Plant, is southeast of the Site and services the CML and the "Wheeler Corridor."

1.4 PHYSICAL CHARACTERISTICS

This paragraph summarizes the geologic setting and the Site-specific conceptual hydrogeologic model based on data collected during the RI and the NEI (appendix A). Hydrogeologic characteristics that affect the model are presented, particularly with respect to features that influence groundwater flow and contaminant transport. Specialized geological terms are further described in the section "Definition of Terms."

1.4.1 Topography

Bounded to the east by Crab Creek and to the south and west by Moses Lake (see figure 1.4-1), the Site is characterized by gently undulating topography. A prominent northwest-trending escarpment in the southern portion of the study area separates the low-lying Cascade Valley from the uplands. The Crab Creek drainage is bounded to the east by another prominent escarpment with a north-northwest trend. Crab Creek drains into the Parker Horn of Moses Lake. Another significant topographic feature within the study area is an elevated, north-trending terrace on the west side of Crab Creek that intersects with the Cascade Valley escarpment in the southern portion of the study area. This fluvial terrace defines the western extent of the valley that is currently occupied by Crab Creek.

The study area lies between two paleochannels that carried a large part of the Columbia River discharge during the late Pleistocene. This area of eastern Washington is sometimes referred to as the channeled scablands, because of the unique erosional features left after glacial outburst floods swept through the area during the Holocene period. Scabland topography that developed on the basalt bedrock is now occupied in part by Crab Creek. The scabland area slopes gently to the south. Portions of this erosional topography, along the northern stretch of Crab Creek, have recently become swampy due to discharge from springs and seeps along the base of the escarpment east of Crab Creek. These localized groundwater discharge areas are apparently due to irrigation on the highlands upgradient and to the north and east of the study area.

The interfluvial area between Crab Creek and Moses Lake slopes gently to the east through a succession of fluvial terraces. The terraces that abruptly terminate at the escarpment east of Moses Lake are partially obscured by abandoned stream channels filled with long bars of basaltic gravel. The highest terraces, located east of Crab Creek and west to northwest of the former LAFB, reflect the earliest stream stages. The terraces on the lower portion of the interfluvial area reflect a period of proglacial stream flow with abundant gravel loads. Only minor changes in topography have occurred since the late Pleistocene, and the surface exposure is dominated by outcrops of Pleistocene and other Quaternary fluvial deposits.

1.4.2 Geologic Setting

Surficial deposits include recent volcanic ash deposits, various undifferentiated and unconsolidated sediments, and soil. Locally, these deposits may affect liquid and vapor transport, because they may form relatively impermeable layers. However, the major geologic formations present in the subsurface that are involved in contaminant transport and are the focus of this study include, from youngest to oldest (figure 1.4-2):

- Hanford Formation.
- Ringold Formation.
- Wanapum Basalt.

Distribution of geologic units within the study area is presented in east-west and north-south cross sections (figures 1.4-4 through 1.4-7). Figure 1.4-3 shows the orientation of the sections.

The term Hanford Formation is a locally used term to describe Pleistocene deposits of outburst floods from Glacial Lake Missoula. The deposits consist of fluvial gravel (boulders to fine sand) primarily composed of rounded basalt, but also included are erosional fragments of the underlying Ringold Formation, granitic and metamorphic rocks, and caliche (Gulick, 1990). The Hanford Formation, which ranges in thickness up to 138 ft near Moses Lake, occurs throughout the study area except for the Crab Creek drainage.

The Ringold Formation is a Pliocene to Pleistocene sequence consisting of medium-fine fluvial clastics, silt, minor clay, and some caliche layers (Gulick, 1990). The surface of the Ringold Formation has been dissected by Pleistocene glacial melt water streams. The Ringold is absent in the east and northeastern portion of the study area and, like the overlying Hanford Formation, increases in thickness westward. The Ringold Formation reaches a maximum observed thickness of greater than 95 ft near the northwest boundary of the study area (at monitoring well 99-AW10 [alluvial well]).

Within the Columbia River Basalt Group, the middle Miocene Wanapum Basalt is situated between the overlying Saddle Mountains Basalt and the underlying Grande Ronde Basalt (Swanson, et al., 1979). Because the Saddle Mountains Basalt is not present in the study area, and the Grande Ronde Basalt is not known to have been affected by site contaminants, they are not a focus of this study.

The Wanapum Basalt is divided into four members, from youngest to oldest: (1) Priest Rapids Member, (2) Roza Member, (3) Frenchman Springs Member, and (4) Eckler Mountain Member (Swanson, et al., 1979). The Eckler Mountain Member is not present at Moses Lake. Small outcrops of the Priest Rapids and Roza Members can be observed in the northeast corner of the study area (Gulick, 1990) along Stratford Road. These same units dip to the southwest and underlie the study area.

In the study area, the Priest Rapids Member consists of the eroded remnants (up to 24 ft thick) of a single aphyric to sparsely olivine- and plagioclase-phyric flow. Maximum thickness occurs in two areas: near the South Base Dump (Site 20) and southwest of the 8-Place Hangar (Site 14). The Priest Rapids appears to occupy a south-trending synclinal trough that plunges to the south (figure 1.4-8). Up axis and along the limbs of the syncline, erosion has stripped off the Priest Rapids.

The Roza Member locally consists of three plagioclase-phyric flows—informally designated Roza 1, Roza 2, and Roza 3 (top to bottom)—with a total thickness of approximately 250 ft. The top two Roza flows have multiple flow lobes of limited areal extent. It is unknown whether Roza 3 has distinct flow lobes. Within most of the study area, Roza 1 has been completely

preserved, but along the flanks of the syncline where the Priest Rapids is absent, an unknown amount of Roza 1 has been removed. In areas unaffected by erosion, Roza 1 increases in thickness south to north, from 98 to 120 ft. At the only USACE well location (Skyline Replacement well) that penetrated both Roza 2 and Roza 3, their thicknesses were approximately 100 ft and 40 ft, respectively. Bulk-rock geochemistry data obtained from samples collected during the NEI (appendix A) confirm the assumption that Roza 1 is always the first Roza Member flow encountered within the study area.

The Roza Member is separated from the underlying Frenchman Springs Member by the Squaw Creek interbed, a sedimentary deposit. Based on drilling for the Skyline Replacement well, the Frenchman Springs Member has at least four flows near Moses Lake, the upper two belonging to the basalt of Sand Hollow and the lower two to the basalt of Ginkgo. The base of the Ginkgo consists of a thick sequence of pillow basalts that forms a major aquifer utilized by public water supply wells.

Within the Wanapum Basalt are sedimentary interbeds belonging to the Ellensburg Formation, one of which (Squaw Creek interbed) is mentioned above (Swanson et al., 1979). In the upper part of the Wanapum in the Moses Lake area, the sedimentary deposits consist of diatomite or fine sand and silt, informally referred to as the Quincy interbed. Stratigraphic relationships are somewhat complex, because in some places the Quincy interbed is intermixed with the flow-top of the uppermost Roza flow, suggesting that the Roza flow invaded loose Quincy deposits. Elsewhere, the Quincy interbed may rest on top of the uppermost Roza flow. Whether it was deposited there or was rafted on top by the advancing Roza flow is not known. It is also possible there are multiple interbeds that are mistakenly considered a single interbed. Where present as a discrete unit, the Quincy does not exceed 2.5 ft in thickness. Stratigraphic relationships imply that the Quincy interbed is, at least in part, older than the uppermost Roza flow and younger than the middle Roza flow. With the exception of a clay interbed, less than 1 ft thick, between Roza 1 and Roza 2 at well location 04-CW04 (CW represents basalt wells with targeted screen interval set within the Roza 2 flow), there is little evidence for deposition of a soil horizon on the middle Roza flow.

1.4.3 Hydrostratigraphic Units

The hydrostratigraphic units relevant to the FS, and their defining characteristics, are identified below and then discussed in further detail:

- Hanford Formation (aquifer in areas, but unsaturated beneath a substantial portion of the Site).
- Ringold Formation (locally semiconfining, locally water bearing, absent in areas).
- Priest Rapids and flow-top of Roza 1 (aquifer).
- Dense flow interior of Roza 1 (aquitard).
- Roza 2 flow-top (aquifer).
- Dense flow interior of Roza 2 (aquitard).

The coarse gravels of the Hanford Formation yield a particularly high hydraulic conductivity (1.0 to 10 centimeter per second [cm/s] or approximately 2,800 to 28,000 ft/day) that is generally orders of magnitude higher than most of the other units encountered during drilling. In contrast, the much finer-grained Ringold Formation, with low hydraulic conductivity (6.3×10^{-6} to 6.0×10^{-4} cm/s or 0.02 to 2 ft/day), semiconfines underlying groundwater within the basalt. Variability in grain size and thickness (or absence) of the Ringold Formation locally alters the effectiveness of this unit as an aquitard. Sandy areas within the Ringold Formation might have conductivities as high as 0.01 cm/s (roughly 30 ft/day).

An idealized basalt flow has the following features that determine fluid and, therefore, contaminant, transport through the flow:

- Brecciated and/or vesicular flow-top.
- Entablature (intensely and randomly jointed basalt).
- Colonnade (massive, vertically jointed columns, with locally abundant horizontal, plate like joints).
- Brecciated and/or vesicular flow-bottom (rarely well developed in Columbia River Basalt flows).

Permeability in basalt flows is controlled by weathering, open joint density, brecciation, and vesiculation. Brecciation and significant vesiculation are essentially restricted to the flow-top. Although jointing is common in the entablature and colonnade of a basalt flow, the joints may or may not be open depending on the amount of overburden pressure. Because much of the upper part of the Priest Rapids flow was removed through erosion, permeability is controlled by depth of weathering and density of open joints. The Roza 1 flow-top is both brecciated and vesicular. Brecciation appears to be a consequence of violent interaction between the lava flow and wet sediments that were incorporated into the flow-top or rafted on top. In contrast, the Roza 2 flow-top exhibits little brecciation but has abundant vesicles. As reported in appendix A and the Site Characterization Technical Memorandum (MWH, 2000), hydraulic conductivity for the Priest Rapids and Roza 1 flow-top ranges from approximately 1.3 to 1,600 ft/day (or 5×10^{-4} to 0.6 cm/s). Roza 2 permeable zones range from 1 to 40 ft/day (4×10^{-4} to 0.01 cm/s). Dense flow interiors (entablature and colonnade) of Roza 1 and Roza 2 should be less permeable. Aquifer test results indicate a hydraulic conductivity of approximately 1×10^{-4} cm/s (0.4 ft/day) for Roza dense flow interior (MWH, 2000). Given these characteristics, flow-tops serve as the major water-bearing zones, and dense flow interiors act as aquitards (that may be leaky).

As a generalization, saturated alluvium (whether Hanford or Ringold) appears to be in hydraulic communication with the uppermost basalt aquifer (Priest Rapids and Roza 1), because seasonal groundwater surface fluctuations are observed in both the alluvial and uppermost basalt aquifers. Fluctuation of groundwater levels in these aquifers is similar both in a temporal sense and in terms of magnitude. Aquifer responses that vary geographically are discussed in section 1.4.5.

The Priest Rapids and flow-top of Roza 1 are considered a single hydrostratigraphic unit, because hydraulic conductivity is believed to be similar and the remnants of the Priest Rapids do not appear to be massive enough to isolate the water-bearing portions of the Priest Rapids from Roza 1. It is conceivable that there are isolated locations where weathering and jointing are

insufficiently developed in the Priest Rapids, and some hydraulic separation between the Priest Rapids and underlying Roza 1 exists. However, based on drilling to date, this possibility is not considered significant enough to affect contaminant transport and selection of remedial alternatives.

1.4.4 Groundwater Occurrence, Flow Directions, and Velocity

Recently collected groundwater elevations for the three principal water-bearing hydrostratigraphic units of concern (alluvium, Priest Rapids-Roza 1, and Roza 2) are presented in figures 1.4-9 to 1.4-11. Generally speaking, groundwater flow is to the south and southwest, although Roza 2 groundwater appears to flow to the west. Based on limited groundwater elevation data from residential wells in Mae Valley that are believed to draw from Roza 1 (appendix A, section A-3.2.1), it appears that groundwater flows toward Moses Lake on the western side of the lake. Head differences between alluvial and basalt aquifers increase downgradient. Based on data collected during the RI/BRA, groundwater flow directions exhibit only minor seasonal variation (typically less than 20 degrees) in the alluvial and Priest Rapids-Roza 1 aquifers, although local variations of up to 40 degrees have been observed in the central portion of the study area south of the runway. Data are not available to show seasonal effects in the Roza 2 aquifer.

Horizontal groundwater gradients in the alluvium are typically 0.004 to 0.006, although in the central part of the study area, between the South Base Dump and the 19th Avenue Dump, the gradient is approximately 0.002 (figure 1.4-9). In Priest Rapids-Roza 1, gradients are generally around 0.002 in the central portion of the study area but steepen to 0.006 in the south (figure 1.4-10). Roza 2 groundwater gradients are apparently much steeper at 0.01 (figure 1.4-11).

Although localized exceptions exist, the dominant vertical gradient is downward from the alluvial aquifer to Priest Rapids-Roza 1 and then downward to Roza 2. Exceptions may be due to effects of groundwater withdrawal from water supply and agricultural wells, as well as infiltration from irrigated farmlands. According to findings in the RI/BRA (MWH, 2003a), the head difference between the alluvial and Priest Rapids-Roza 1 aquifers is approximately 0.5 ft in the northern portion of the study area and increases to more than 15 ft in the south. In the area around Site 20, the gradient may reverse and become upward. These differences represent seasonal maxima, with the greatest difference found in the summer and fall. Data are not available to show seasonal variations between the Priest Rapids-Roza 1 and Roza 2 aquifers, but winter head differences range from zero to more than 20 ft. Because of the apparently nonuniform pattern of the Roza 2 potentiometric surface, head differences between these basalt aquifers do not vary systematically across the Site.

Groundwater flow velocities have been determined (table 1.4-1) for the main water-bearing units, based on the following relationship:

$$v = K * i / n_e$$

In this equation, “v” is velocity, “K” is hydraulic conductivity, “i” is horizontal gradient, and “n_e” is effective porosity. The effective porosity represents that portion of the pore space that

participates in flow and is generally less than the total porosity. Depending on subsurface heterogeneity, effective porosity and hydraulic conductivity may vary considerably. For the purposes of overall site characterization, representative values have been selected that should provide reasonable groundwater flow velocities for each water-bearing unit when viewed on the scale of the study area. Therefore, these velocities may not be valid on a local scale.

An additional factor to consider is that the hydraulic conductivity values are derived mainly from slug tests, the results of which are considered order-of-magnitude estimates and tend to underestimate actual aquifer conductivity. By way of comparison, a slug test of 99-BW17 (BW represents basalt well with targeted screen interval set within the Priest Rapids and/or Roza 1 flow) yielded a hydraulic conductivity of approximately 640 ft/day, whereas the average obtained from constant discharge and recovery tests yielded approximately 1,600 ft/day (MWH, 2000). For the aquifer tests, 99-BW17 was an observation well adjacent to pumping well 99-BW05.

Taking this simplistic approach, the basalt aquifers have groundwater velocities at up to two orders of magnitude lower than that of the Hanford Formation but one to two orders of magnitude higher than the Ringold.

1.4.5 Groundwater Recharge and Discharge

Potential sources of groundwater recharge to the subsurface include:

- Precipitation.
- Subsurface groundwater from upgradient portions of the aquifer.
- Groundwater infiltration from the Larson WWTP (figure 1.4-1).
- Infiltration of irrigation water.

With a semiarid to arid climate, Moses Lake gets an average of approximately 8 inches of precipitation per year, with most occurring from October through March. Of this, much (80 percent or more) is probably lost to evapotranspiration and never reaches the groundwater. As reported in the RI/BRA based on communications with personnel in the CML Wastewater Division, groundwater recharge to the Hanford Formation from the Larson WWTP was estimated at 350,000 to 400,000 gpd (390 to 450 ac-ft/year). Another source of recharge to the Hanford Formation is irrigation water during the growing season (approximately mid-April to November), estimated to be as much as 0.8 ac-ft/ac/year (Ms. Marcia Knadle, USEPA, personal communication, 2003). The source of this water might be pumped groundwater from local aquifers or imported water (from surface water bodies like the Columbia River). Fluctuations in water levels in Hanford Formation monitoring wells appear to correlate with recharge during the growing season, although it could be a delayed or out-of-phase response to pumping from irrigation wells.

The primary sources of groundwater discharge from the upper hydrostratigraphic units (Hanford Formation, Priest Rapids and Roza aquifers) are irrigation wells, smaller public water supply systems, and residential wells. Combined discharge from these sources may approach 10^8 or even 10^9 gallons per year (MWH, 2003a), although accurate calculations are difficult because

discharge rates are not closely monitored or regulated. Larger public water supply systems, such as the CML, draw primarily from deeper aquifer sources than the Roza. There may also be some discharge to Moses Lake, Lewis Horn, and Parker Horn.

1.5 CONCEPTUAL SITE MODEL

A CSM is a schematic and narrative representation that describes chemical sources, affected media, potential chemical transport mechanisms, and modes of exposure for human or ecological receptors. Throughout investigations, the CSM is used iteratively to identify and refine data gaps, and is used in developing the Project Quality Objectives to drive the sampling and analytical decisions. At the FS stage, the CSM guides development of remedial actions. The topics discussed in this section are as follows:

- Historic knowledge of TCE contamination at the Site.
- The physical system into which the TCE has been released and is transported.
- The anticipated fate and transport of TCE based on literature review and some specific site knowledge.
- Identification of preliminary areas of concern.
- Data gaps and uncertainty.

Figure 1.5-1 displays the exposure CSM as traditionally presented in risk assessments. This version is slightly updated from the Final RI/BRA Report (MWH, 2003a) to incorporate soil vapor results presented in the NEI (appendix A). Figure 1.5-2 displays the possible pathways of TCE release, reorganized to represent the fate and transport of TCE in context of the physical layout of the Site.

1.5.1 Chemicals of Potential Concern

The RI/FS process iteratively develops and refines lists of chemicals to focus the investigation, the risk evaluation, and finally the selection of GRAs and comparison of alternatives. COPC are compounds that are retained after a preliminary risk and regulatory screening in the RI/BRA. The media-specific screening criteria that were used in the selection of COPC in the RI/BRA were the USEPA list of Region 9 Tap Water preliminary remediation goals (October 2002) and the amended (February 12, 2001) MTCA Method A groundwater cleanup levels. In accordance with USEPA Region 10 policy, maximum detected concentrations of carcinogenic chemicals in each medium were evaluated based on a chemical-specific target risk level. The chemical-specific target risk level was 1.0×10^{-6} . Noncarcinogenic chemicals were evaluated using a target hazard quotient (HQ) of 0.1 (i.e., one-tenth of the applicable screening criteria). Consistent with discussions between USACE and USEPA Region 10, the MCL and MTCA Method A groundwater cleanup level, both equal to 5 micrograms per liter ($\mu\text{g/L}$), were used to select the screening level for TCE in groundwater.

Two COPC lists relate to groundwater in the Study Area, one derived from groundwater data and representing compounds known to be there, and one derived from review of chemicals in soil, which could potentially affect groundwater. The SSFS describes the latter list of compounds.

1.5.1.1 Groundwater-Data Derived COPC

In the RI/BRA (MWH, 2004a), screening for human health COPC was conducted for groundwater using water data that had been acquired as of 2003. This section also includes updates information from the NEI.

The RI/BRA (table 6.48) summarized compounds of potential concern for groundwater as follows:

Hanford/Ringold Formation

- 1,2,4-Trimethylbenzene
- 1,3,5-Trimethylbenzene
- Bromodichloromethane
- Dibromochloromethane
- TCE

Drinking Water Wells

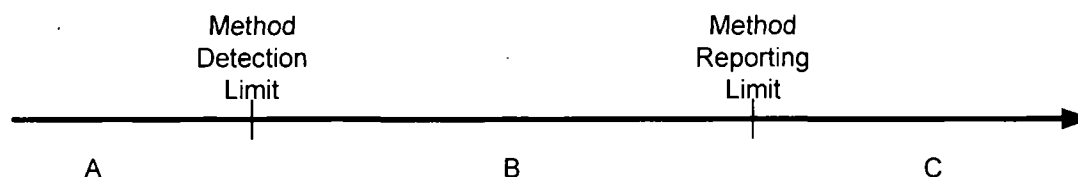
- Bromodichloromethane
- Dibromochloromethane
- TCE
- Methyl tertiary butyl ether (MTBE)

Priest Rapids-Roza Members

- Acetone
- Manganese
- Benzene
- MTBE
- TCE

During the development of the GWFS, additional analysis was conducted to identify chemicals for which site-wide impacts to groundwater have been demonstrated, or for which a lack of groundwater impact may not be determined with confidence due to elevated detection limits for individual sample results. The results of this analysis (Appendix B, *Site-Wide Groundwater Data Analysis*) were used to evaluate which COCs need to have PRAGs developed in the GWFS. The results of the analysis were also used to assist in identifying any surface-soil-related COPCs to be protective of groundwater. (The two trimethylbenzene compounds were dropped based upon this analysis.)

The process used in the *Site-Wide Groundwater Data Analysis* is briefly summarized as follows:



- The horizontal line shows increasing concentration for a chemical. The method detection limit (MDL) is the chemical-specific value that defines whether the laboratory can positively identify the presence of a chemical in the sample. The method reporting limit (MRL) is that value that the laboratory can report as a quantity with 95 percent statistical confidence or greater. Ecology also maintains a list of practical quantitation limits (PQLs). PQLs are reporting limits that are regularly attained by good laboratories

(http://www.ecy.wa.gov/programs/tcp/policies/pql_w.xls). The list was used to assure that MRLs used were adequate.

- Chemicals included in screening.
- All chemicals with positive detections in groundwater (represented by *C*) and detected “estimated” results (represented by *B*) were retained to determine whether they should be groundwater COPCs.
- Non-detected chemicals (represented by *A*) that had reporting limits elevated above risk based values or listed PQLs were retained.
- Values used for the screening.
- For chemicals for which the maximum MRL was equal to or greater than the PQL, maximum quantities or maximum “estimated” values (*B* or *C*) were retained for screening against risk and legal requirements.
- For chemicals reported as non-detects (*A*), the chemical was screened against risk and legal requirements using the maximum MDL.

Appendix B, table B-2, shows groundwater COPCs, and the basis for retaining them.

- Chemical values were compared to groundwater regulatory standards or risk-based screening criteria (columns E through L in table B-2). Exceedance of a criterion is indicated in yellow highlighting.
- If the Federal MCL was exceeded by a maximum detected value or sample detection limit (or PQL if a sample detection limit is unavailable), then the MCL is highlighted in red.
- Cancer risk and/or noncancer hazard estimates were used to evaluate the significance of an exceedance of a risk-based criterion (table B-2).
- If the resulting risk or hazard estimate is below the USEPA’s risk management range of 10^{-6} to 10^{-4} and HQ of 1, then the estimate is not highlighted. If the risk or hazard estimate is within the USEPA’s risk management range, then the estimate was highlighted in orange. If the risk or hazard estimate exceeded the USEPA’s risk management range, then the estimate was highlighted in red.
- The chemical names in column A were highlighted to reflect results of the overall evaluation.

Based on this procedure, the chemicals were categorized as to their potential to impact groundwater as described below:

Category 1. Detected chemicals that have adversely impacted groundwater, or may potentially impact groundwater. These are defined as detected chemicals with maximum concentrations in excess of the Federal MCL or USEPA’s risk management range. Category 1 chemicals include acetone, manganese, and TCE. Arsenic was excluded from this list, because it was demonstrated to represent ambient conditions in the Final RI/BRA report.

- Acetone was retained as a groundwater COPC, pending further review of groundwater monitoring data and additional information. Acetone was detected in only one well, and may have resulted from well construction materials.² However, USEPA and USACE jointly determined that further review of the data and supplemental information should be performed prior to making a final decision on this chemical. Acetone was retained as a COPC with a case-by-case basis.
- Manganese was retained as groundwater COPC. It should be noted, however, that the maximum manganese concentration of 180 (µg/L) exceeds the Federal secondary MCL, but does not exceed any risk-based criteria. The Federal MCL for manganese (50 µg/L) is a nonenforceable standard based on the taste and odor threshold for this chemical. (The regulatory use of the secondary groundwater standard in establishing CERCLA cleanup levels is further discussed in chapter 2.)
- TCE was retained as a general groundwater COPC.

Category 2. Detected chemicals that exceed one or more risk-based screening criteria, but for which the maximum concentration is within USEPA's risk management range. Category 2 includes only MTBE. This data analysis proposes that MTBE should be excluded as a potential groundwater COPC because:

- MTBE was detected in only 3 of 260 groundwater samples.
- Concentrations are within the USEPA's risk management range.

Category 3. Trace analytes for which the estimated concentration is within the USEPA's risk management range. Category 3 chemicals include: bromodichloromethane, carbon tetrachloride, dibromochloromethane, and dibromo-3-chloropropane. These chemicals were not retained as groundwater COPCs because:

- They were detected at very low levels.
- They were each detected in only one sample out of a range of samples (based on the compound) from 249 to 260 in size.
- Concentrations are within the USEPA's risk management range.
- The detected value is below Ecology's PQL for carbon tetrachloride.
- The brominated chloromethanes are common secondary by-products of water treatment by chlorination.
- Benzene has been detected at very low frequency, never exceeded its MCL, and most of these detections were from well 91-AW15, which is associated with an Independent Remedial Action for a petrochemical release; that site has not been included in the Site-wide investigation because of its independent status. Well 00-BW01 had a Region 9

² While there is insufficient information to definitively state that acetone in the well is due to this source, several reports have been brought to our attention by USEPA Region 10 (Knadle, pers. comm., 2005) that suggest that coated bentonite pellets used in well seals may include isopropanol and acetone, or that hydrolysis of isopropanol during curing may generate acetone. Some states have determined certain kinds of coated bentonite inappropriate to use. For example: <http://www.deq.state.mi.us/documents/deq-wd-gws-wcu-coatedbentonitetabs.pdf>.

preliminary remediation goal exceedance by 40 percent (corresponding to 1.4×10^{-6} incremental cancer risk). During the NEI, very few benzene detections occurred; however, wells 04-C01 and 04-CW07 reported exceedances equivalent to 2.3 and 3.5×10^{-6} incremental cancer risk.

Category 4. Non-detected chemicals for which maximum detection limits (or PQLs, if a sample detection limit is unavailable) exceed the Federal MCL or the USEPA's risk management range. The only Category 4 chemical is toxaphene. However, toxaphene is not retained as a potential Study-area-wide groundwater COPC because:

- Toxaphene is a pesticide that was used primarily on cotton and other agricultural products and would most likely be attributable to regional agricultural sources. (For example, go to <http://www.epa.gov/glnpo/bnw/pesticides/PestRep003.pdf>.) A brief review of literature suggests that the USAF use of toxaphene is associated with shipment or staging of other pesticides, but there is no documented or suspected use of toxaphene or, for that matter, shipping of other pesticides at the Site.

Category 5. Non-detect chemicals for which maximum detection limits (or PQLs if the sample-specific detection limit is unavailable) fall within the USEPA's risk management range. Category 5 chemicals include: aldrin, alpha-BHC, dieldrin, and heptachlor. These chemicals were not retained as groundwater COPCs because:

- They were not detected.
- Should they be present at concentrations below the MDL, the concentrations would be within USEPA's risk management range.
- The chemicals are likely to have been used as permitted pesticides in nearby agriculture and hence, if present, may not represent a "release" in the sense of the NCP.

Category 6. Detected chemicals, trace analytes, or non-detect analytes for which Federal MCLs or risk-based criteria are unavailable. Category 6 chemicals include: 1,3-dichloropropane, 2-hexanone (i.e., methyl butyl ketone), 4-isopropyltoluene (cymene), and methane.

- Structurally similar surrogates were identified for 1,3-dichloropropane, 2-hexanone, and 4-isopropyltoluene, and MCLs or risk-based criteria for these surrogates were used for COPC screening (appendix B, table B-2).
- 1,3-dichloropropene was used as a surrogate for 1,3-dichloropropane.
- Methyl isobutyl ketone was used as a surrogate for 2-hexanone (methyl butyl ketone).
- Isopropylbenzene (cumene) was used as a surrogate for 4-isopropyltoluene (cymene).

Use of these surrogates is believed protective based on structure-activity relationships and toxicological properties for these chemicals. In all cases, maximum detected concentrations or detection limits for these chemicals were below available MCLs or risk-based criteria for surrogates. Methane was a chemical measured for determining the natural attenuation propensity of the groundwater, and no toxicity criteria are available; therefore, this chemical was not retained as a groundwater COPC for evaluation.

All Semi-Volatile Organic Compounds (including polyaromatic hydrocarbons [PAHs]) were eliminated as COPCs during the initial screening step because the RI/BRA report's maximum MRLs do not exceed standard laboratory PQLs.

It should be noted that groundwater samples were not analyzed for PAHs by Method 8270C Selective Ion Monitoring (SIM), which has lower MDLs and reporting limits than does the standard Method 8270C. However, this lack of SIM analysis was in accordance with the decision logic included in the approved Field Sampling Plan (MWH, 1999b). As described in section 4.3 of the cited plan, if volatile petroleum hydrocarbons (i.e., MTBE and benzene, toluene, ethylbenzene, and xylenes) are detected in a sample collected from a given monitoring well, then the well will also be sampled for petroleum hydrocarbons in the gasoline, diesel, and motor oil ranges. If the results of that analysis indicated there are petroleum hydrocarbons present, then the sample would be analyzed again for the range of hydrocarbons that were indicated by the identification method, and for carcinogenic (c) PAHs by Method 8270C SIM.

During the June 2000 and September/October 2000 groundwater monitoring events, groundwater samples were collected from 18 monitoring wells and analyzed for a variety of petroleum chemicals (gasoline, diesel, and oil ranges). In all cases, results of hydrocarbon screens for these fractions were non-detect. Therefore, analysis for cPAHs by Method 8270C SIM was not performed, consistent with the Field Sampling Plan.

In 1992, the underground storage tank area associated with Pump House No. 1 was found to have petroleum contamination in groundwater and soils by a site user subsequent to occupation by the DOD. An Independent Remedial Action under the MTCA is being performed at that site by the Port of Moses Lake, represented by Exxon (Secor, 1997). A long-term monitoring plan is being carried out at this Site under the direction of Ecology. The pump house appears to be hydraulically upgradient of TCE concentrations detected in groundwater in the Study Area. This groundwater and soil contamination represents a local impact from petroleum hydrocarbons and, likely, PAHs; however, it does not represent a systematic, Study-area-wide impact to groundwater from either of these suites of compounds.

Additional Information since the RI/BRA Report. The NEI results (appendix A) additionally detected cis-DCE (dichloroethene), perchlorethylene, chloroform, and bromoform, but none was above the USEPA Region 9 preliminary remediation goals at 10^{-6} incremental lifetime cancer risk or 0.1 HQ; and hence these findings do not add them to the list of COPCs.

In summary, the list of COPC for groundwater based on measurements from wells comprises only manganese, acetone, and TCE. All but TCE have limited occurrence in the Study Area. Pump House 1 may have additional COPCs associated with the jet fuel spill, but these compounds are not considered further here because that area is subject to a parallel remedial action.

1.5.1.2 Soil-Data Derived COPCs

The effect of soil contaminants in the vadose zone on future groundwater relies largely on environmental transport and fate estimates. Soil COPCs are thus determined with greater uncertainty because it is necessary to estimate possible mobility to the groundwater.

Two appendices are attached to show the means of determining the soil COPCs. The appendices are Appendix C, *Evaluation of the Potential Shallow Soil Migration to Groundwater for Non-Volatile Organic and Inorganic Contaminants*, and Appendix D, *Evaluation of the Potential Shallow Soil Migration to Groundwater for Volatile Organic Contaminants*.

In appendix C, all groundwater compounds in appendix B that were identified as potentially above screening levels (that is, those in table B-2 that are highlighted in color) were subjected to further analysis using soil results and estimating mobility to groundwater. The details of the calculations are provided in the appendix. Table C-1 lists the 38 compounds that were selected. Additional considerations were required to estimate impacts from volatile compounds such as TCE. Appendix D describes the calculations that relate the soil vapor results to the mobility calculations.

Resulting estimated concentrations in groundwater were compared to a hierarchy of values to determine whether compounds should be retained as COPC:

- MCL, if one exists for the compound.
- If not, then MTCA Method A groundwater values.
- If neither MCL nor MTCA Method A values existed, then MTCA-B values.
- If these have not been established, the USEPA Region 9 Tap Water preliminary remediation goals.

Table 1.5-1 summarizes the surface soil screening results for compounds by PSA. There are 11 soil-specific compounds or compound suites (polychlorinated biphenyls and PAH) and petroleum are suggested by this table to potentially impact groundwater. These soil-specific compounds are discussed further in the SSFS.

The key compound known to be in groundwater, TCE, is listed in table 1.5-1 for PSA 19 (the former Liquid Oxygen [LOX] Plant). The Interim Removal Action (IRA) involved pulling two sumps containing TCE sludge, as well as excavating nearby impacted soils. The soil gas value of 5,300 parts per billion by volume (ppbv) was used to demarcate possible adversely impacted groundwater during the IRA. The foundation for 5,300 ppbv is presented in appendix D (page D-4). Data from appendix A (NEI) provide evidence that the TCE soil vapor values have substantially subsided in the 4 years since the IRA. During the NEI at PSA 19, no soil vapor value was detected above a reporting limit of 1,000 ppbv. Additionally, the alluvial aquifer directly beneath the former primary sump at PSA 19 showed a concentration of 1 µg/L TCE. Accordingly, PSA 19 does not appear to be currently impacting groundwater above the TCE MCL of 5 µg/L.

1.5.2 PSAs and Release Mechanisms

According to site records (as-built diagrams and personnel interviews), TCE was apparently used as a solvent degreaser in various industrial settings at the former LAFB by governmental and nongovernmental entities at least into the 1960s. Drums, underground tanks, and sumps have been removed in the intervening years, with the most recent removal at the LOX site by USACE in 2000 (MWH, 2003a).

Initial TCE releases may have occurred from numerous surface areas of industrial activity, called PSAs in the *Site Screening Technical Memorandum* (MWH, 2003b). Three general activity categories comprise the potential method of TCE releases:

- Disposal of spent solvent (mixtures of TCE, oil, and grease) directly into landfills or placement of containers, such as drums, in landfills.
- Discharge of TCE (either as dilute aqueous solutions or as spent solvent) to the surface (for example, on tarmac or soil adjacent to a runway).
- Disposal or drainage of TCE into a sump, pit, septic tank, drain system, or industrial WWTP.

Despite numerous investigations at the Site, no direct evidence exists for the presence (or nature) of ongoing sources. Indirect evidence, in the form of low-level soil gas and dissolved-phase data, strongly suggests that existing sources are residual.

The following discussion presents hypothetical behavior of TCE in the subsurface. The activity-based modes of release listed above could have resulted in introduction of TCE as a dissolved or as a non-aqueous phase (NAPL) into the unsaturated (vadose) soil zone. When compared to the density of water, NAPLs that sink (which includes TCE) are referred to as denser-than-water NAPLs (or DNAPLs). Thus, subsurface site soils would have been the initial “reservoirs” of TCE. Depending on quantity and rate of release of TCE, migration through the vadose zone to the saturated zone would subsequently occur, either through continued migration of mobile NAPL or entrainment in dissolved phase in infiltrating precipitation. The saturated zone would then represent a second “reservoir” for TCE as dissolved-phase and/or DNAPL-phase TCE. Section 1.5.3 describes the relevant physical and chemical properties of TCE as they relate to partitioning and movement within various environmental media. Modes of exposure of human and ecological receptors were discussed in detail in the Risk Assessment section of the RI/BRA report.

Historic input rates of solvent to the aquifer are generally unknown. Based on general language from discharge permits, solvent releases could have included petroleum and halogenated solvents, and no information is available for TCE content of effluent. Depending on frequency, quantity, and areal impact (for example, point source for dry well vs. broad area for trenches and landfills), rate of migration to groundwater and likelihood of encountering residual or mobile NAPL may vary from source area to source area.

Most, if not all, of the facilities at the Site that may have used TCE had dry wells, industrial waste septic tanks, leach fields, and leach pits that could have received spent solvent. In addition, based upon experiences at other bases and industrial facilities, landfills could have received TCE, some of which could have been burned in place to facilitate destruction. Depending on the completeness of combustion, unknown amounts of TCE may have infiltrated the subsurface. However, despite known or suspected activities that may have contaminated subsurface soils, no ongoing sources of TCE in shallow soil at the Site have been identified, with the exception of Site 19 (LOX Plant). An interim removal action was conducted at PSA 19 to remove a source of TCE-containing sludge and water in a sump, and post-removal confirmation sampling showed that TCE soil gas concentrations at this location are declining. Consequently,

the SSFS concluded that shallow soil sources are not a priority concern in terms of their impact to groundwater and, therefore, do not warrant future remedial actions to reduce the concentration of TCE in shallow soils.

1.5.3 Contaminant Fate and Transport

This section describes the generalized environmental fate and movement of TCE in the vadose and saturated zones. Section 1.5.3.3 identifies site-specific features that influence contaminant transport, as well as observations about current contaminant nature and extent, and present implications for existence of ongoing sources. The CSM is given further area-specific development in section 1.5.4.

1.5.3.1 Vadose Zone

Upon release of TCE into the vadose zone, TCE exists as a three- or four-phase system. The phases are:

- NAPL (at the time of release, presumed to be DNAPL, although mixtures with significant amounts of oil and grease may be lighter-than-water (LNAPL)).
- Water-dissolved TCE.
- Soil-adsorbed TCE (associated with organic carbon in the soil).
- Soil vapor.

These phases, whether mobile (NAPL, water-dissolved, or vapor) or immobile (residual NAPL or soil adsorbed), may act as sources for groundwater contamination. As water passes through the vadose zone, on contact with NAPL, adsorbed TCE, or TCE soil vapor, some TCE will partition into water in concentrations governed by partition coefficients for the four phases and exchanges (NAPL versus water, organic carbon versus water, and gas versus water). Movement of dissolved-phase TCE through the vadose zone is governed by infiltration rate and by density, in that water is denser than the air that it displaces as it moves in void spaces. Ultimately, this dissolved-phase TCE reaches the saturated zone and contributes to groundwater contamination.

TCE DNAPL in the vadose zone would exist as a film, ring, or wedge of DNAPL-wetted soil. Halogenated solvent DNAPLs such as TCE generally do not spread as a film because of internal cohesion (Cohen and Mercer, 1993). TCE-dominated halogenated solvent mixtures are heavier than water, and TCE is one of the more mobile halogenated DNAPLs (Cohen and Mercer, 1993). As specific gravity increases and viscosity decreases, the potential for DNAPL movement increases. As a pure substance, TCE has a high specific gravity of about 1.48 and a moderately low absolute viscosity of about 0.57 centipoise (Cohen and Mercer, 1993). Mixtures of petroleum hydrocarbons and TCE (as generated from degreasing operations) would have properties that vary significantly from that of pure TCE.

In the vadose zone, TCE DNAPL would displace air relatively easily, thereby wetting the soil and migrating as a leading mass resembling a comet, with a trailing network of droplets that are at residual saturation. Residual saturation is the fractional volume of immobile NAPL in the total void space of the soil. This reservoir of vadose zone residual NAPL would be subject to

dissolution and volatilization losses over time. By comparison, in the saturated zone, water must be displaced away from the soil void spaces in order for TCE migration to occur, and thus TCE DNAPL must overcome more resistance. Should DNAPL encounter a penetration-resistant layer, such as a finer-grained sediment lens or bedding layer, it may pool there or respond to gravity and continue to migrate in another down-gravity direction.

Migration rates of DNAPL bodies in air-saturated and water-saturated soils are proportional to the fluid density differences between TCE DNAPL and air in the vadose zone, and DNAPL and water in the saturated zone. The fluid density difference from air is greater than that for water; hence, mobility would be relatively high for TCE in the vadose zone. TCE DNAPL would be expected to move relatively rapidly through the vadose zone unless a barrier to fluid flow is present. As the material moves through the vadose zone, lateral displacement may occur due to preferential flow paths or partial barriers.

The ability of DNAPL to reach groundwater would depend upon the quantity and frequency (continuous or intermittent) of the release. If a constant or substantial intermittent discharge of DNAPL at a given location occurred historically, the presence of soil with residual TCE would facilitate development of preferential pathways and permit rapid flow to groundwater.

1.5.3.2 Saturated Zone

Capillary Fringe

Entry of TCE DNAPL into the saturated zone entails overcoming increasing resistance to flow. DNAPL head must be greater than capillary resistance in order to displace water within soil pores and to wet the soil with itself. This resistance is called threshold entry pressure, and the variables that govern the process in aquifers are (Cohen and Mercer, 1993):

- Soil pore size distribution.
- Soil wettability with DNAPL.
- Fluid viscosity ration and density ratios.
- Interfacial tension.
- Gravity/buoyancy.
- Hydraulic gradients.

As a consequence of encountering these resistances at the capillary fringe, TCE DNAPL may linger in this region until sufficient DNAPL mass accumulates to provide a head to overcome the resistance.

DNAPL in Alluvium and Basalt

The influences mentioned above for the capillary zone also govern TCE migration within aquifers. In general, DNAPL residual saturation will be greater (and migration potential less) in finer grain size soils due to smaller pore spaces than in coarse soils or fractured media. A great

deal has been written on the migration of DNAPL in complexly fractured rock, but much less is known of fractured basalt occurring in stacked, laterally extensive sheet flows.

DNAPL flow follows a gravity gradient but on a complex path based on the number, density, size, and direction of joints or fractures in such a system. Relatively small amounts of DNAPL may deeply penetrate fractured bedrock, forming highly disseminated pockets as opposed to pools or coherent masses. DNAPL migration will continue until the main DNAPL body is exhausted by losses to the pore spaces at residual saturation.

Sorbed and Dissolved-Phase TCE in Groundwater

The instantaneous, measured dissolved concentration of TCE at a well will depend upon:

- Quantity sorbed to the geological formation or organic substances in the vicinity of the well.
- Dissolved concentrations from upgradient (in both the horizontal and vertical sense) sources.
- Advective flow rates and dispersion.
- Location of the well relative to the source (lateral place in the plume).
- Monitoring well screened interval (vertical place in the plume).

Within aquifers, dissolved-phase TCE would be transported down the hydraulic gradient at a rate consistent with the horizontal conductivities and sorption to aquifer materials. Similarly, migration of TCE between aquifers would be governed by vertical gradient, vertical conductivity, and sorption to aquifer materials.

In dissolved phase, TCE is subject to natural attenuation processes, which may include physical, chemical, and biological processes. Physical processes, such as dispersion and diffusion, serve to diminish TCE concentrations by spreading a given mass of contaminant through a larger volume of water. As such, physical processes dilute, but do not destroy, contaminants. Chemical processes bind contaminants to aquifer materials (as in adsorption) or otherwise render them immobile. Because these processes are reversible, the contaminants may represent a continued source. Biological processes involve reactions between bacteria, common ions in groundwater, and contaminants. These biodegradation processes achieve the destruction of the contaminant, although, in the case of TCE, more toxic degradation products (like vinyl chloride) may result. For TCE, biodegradation occurs most favorably under anaerobic conditions.

1.5.3.3 Implications for Existence of Ongoing Sources

This section summarizes pertinent findings of previous investigations and evaluates their implications for the nature of ongoing sources. Data and observations relevant to a summary of fate and transport processes are listed below:

- The coarse and porous soils of the Hanford Formation are not conducive to retention of a significant reservoir of TCE NAPL, given the 40 years or more that have elapsed since

suspected source areas were active. Remaining sources, if any, in the vadose zone are likely to be residual or soil sorbed.

- The arid-to-semiarid climate at the Site means that infiltration rates (from precipitation) are low; therefore, mass transfer of TCE from residual sources in the vadose zone (if present) is minimized.
- Soil gas data are inconsistent with ongoing, shallow vadose zone NAPL sources. Existing soil vapor levels of TCE do not appear to significantly contribute to dissolved TCE levels in groundwater (appendix D), with the single exception of one measurement for the South Base Dump (see below).
- Relatively unvarying dissolved-phase TCE concentrations are observed over a wide area in groundwater, which suggests that ongoing sources may exist.
- A general lack of other solvents or petroleum-related compounds in groundwater implies an unmixed source (that is to say, a source consisting predominantly of TCE).
- Strong indicators of mobile NAPL (for example, high concentrations of TCE in soil, soil gas, or groundwater at or immediately downgradient of suspected source areas) are lacking. The absence of strong indicators suggests that any ongoing sources are, at worst, residual NAPL or soil-sorbed TCE.
- Dissolved-phase concentrations are significantly lower in the alluvial aquifer ($<5 \mu\text{g/L}$) than in basalt aquifers (up to at least $88 \mu\text{g/L}$).
- Seasonal groundwater elevation fluctuations of as much as 2 ft in the alluvial aquifer may encourage a “smear” or capillary fringe zone for DNAPLs such as TCE, although the coarse grain size of the Hanford Formation may limit the ability of the formation to retain DNAPL. Investigations at Site 19, which were specifically targeted at identifying a smear zone, were unsuccessful at finding NAPL of any kind. Although findings at Site 19 may not be applicable to other PSAs, it is assumed for this FS that smear zones are not important sources of TCE.
- Fine-grained soils of the Ringold Formation, through which groundwater moves very slowly, may have trapped residual NAPL or soil-sorbed TCE that could represent a long-term (but low-level) source of TCE, both for the overlying Hanford Formation and the underlying Priest Rapids-Roza 1 aquifer.
- Based on Total Organic Carbon (TOC) results (<500 milligrams [mg]/kilograms [kg]) reported from the NEI (appendix A), there does not appear to be an organic component to soil horizons or weathered zones associated with basalt flow-tops. Therefore, the sorbed contribution associated with the basalt aquifers is likely to be insignificant.

Features that contribute to uncertainty about the nature of sources include:

- Because of difficulties associated with sampling flood gravel deposits during drilling, it is often difficult to identify the presence of layers of relatively low conductivity that may have influenced contaminant migration through the vadose zone. Some bedding structures have been observed in outcrops at local gravel pits. Based on these observations, localized differences in hydraulic conductivity may occur in the flood-

deposited gravels and sands of the Hanford Formation, so that some lateral displacement away from the source could occur.

- The existing monitoring well network is not ideally suited to pinpointing active sources.
- If mobile NAPL were present in basalt, variations due to erosion of flow-tops, juxtaposition of flow margins, vesiculation, brecciation, and jointing might encourage preferential (and unpredictable) flow and prevent source delineation.
- Due to a high average flow rate in the Hanford Formation, the chance of encountering a significant concentration of TCE (except very close to an ongoing source) in this aquifer appears slim.
- With the exception of PSA 19, soil gas investigations at the site were limited to shallow depths and may not provide adequate characterization of deeper vadose zone soils.

In none of the investigations at the Site was subsurface DNAPL encountered or inferred from measurements. Both the location and the relationship of subsurface sources to surface release areas are uncertain. For this reason, it is not possible to directly estimate the amount of TCE source. Note that an inferred subsurface source could include mobile NAPL, residual NAPL, or soil-sorbed TCE, each of which would contribute TCE through dissolution and migration to groundwater. Aside from actually encountering free product in the subsurface, the chief indicators that would imply existence of appreciable quantities of mobile NAPL include a high concentration of TCE in soil, soil gas, or groundwater at or immediately downgradient of the source. The absence of strong indicators of presence of mobile NAPL suggests that any ongoing sources are, at worst, residual NAPL or soil-sorbed TCE. In practice, it may not be possible to say whether the inferred source of TCE to groundwater is residual NAPL or soil sorbed, when the only information available is from soil gas or dissolved TCE in downgradient groundwater.

None of the PSAs, with the exception of PSA 19, contains direct evidence for existence of a persistent source in the vadose zone. At PSA 19, high concentrations of TCE in sump liquids and in soil gas suggest that TCE product may have been released. However, the apparent absence of TCE in groundwater near Site 19 seems to contradict the hypothesis that the waste disposal system was a significant source for groundwater.

Based on logic developed in appendix D and in the SSFS, of the known PSAs for which soil gas data are available, only Sites 19 and 20 provided evidence suggestive of recent vadose zone TCE sources. At Site 19, high concentrations of TCE in sump liquids and in soil gas—well in excess of the 5,300 ppbv level considered a potential threat to groundwater (see appendix D for this calculation)—suggest that TCE may have been released into vadose soils at significant levels. However, the apparent absence of TCE in groundwater near Site 19 seems to indicate that the release did not represent a significant source for groundwater contamination, at least with regard to observable impact today. Since removal of the sumps in 2000, TCE in soil vapor has decreased markedly, such that in 2004 the soil gas concentrations throughout the vadose zone had dropped below the Method 8265 reporting limit of approximately 1,000 ppbv (see appendix A). It is believed that removal of the sump and associated contaminated soil allowed diffusion and barometric pumping to purge soil vapor. At present, soil gas at Site 19 is not considered to represent an ongoing source to groundwater.

At Site 20, the maximum concentration of TCE detected in soil gas (57 ppbv) is suggestive of a vadose zone source, because it is between two and three orders of magnitude of the calculated groundwater protection level of 5,300 ppbv.³ Despite extensive trenching at the Site 20 landfill and multiple soil gas readings, a source was not located. It is possible that any source remaining in the vadose zone may exist at a depth greater than the maximum depth of investigation (20-25 ft bgs depending on location).

The results of previous investigations that show low concentrations of dissolved-phase TCE in the alluvial aquifer could support a preliminary conclusion that residual TCE NAPL, if present at this time in the vadose zone, is a relatively minor source for TCE to groundwater. However, the low observed concentrations could also be an artifact of the much greater flow rate of water in the alluvial aquifer and paucity of monitoring wells proximal to sources. High flow rates restrict residence time of groundwater in contact with NAPL, thereby resulting in dissolved-phase concentrations well below the solubility limit. Size of the remaining, yet undiscovered, source(s) also plays a role, in that a NAPL source with a small footprint and low mass would not be influential over a great distance, which would make monitoring well locations critical.

The presence of a basalt aquifer-based TCE source or sources may be inferred from the greater concentrations of TCE in basalt compared to alluvial aquifers and the relatively stable TCE concentrations throughout the dissolved-phase plumes. Given the low concentrations of TCE seen in wells, there are no indications that suggest the presence of a mobile NAPL source. However, the exact nature of the source is difficult to infer without direct observation or knowledge of TCE concentrations in areas immediately downgradient of the source.

It cannot be ruled out that sources might exist in the vadose zone that contribute to the currently observed dissolved-phase TCE in the basalt aquifers. Efforts to identify vadose profiles of TCE vapor were frustrated during the investigations at all sites with the exception of Site 19, due to the inability of direct-push equipment to penetrate the cobbled alluvium. Multi-level soil-vapor monitoring wells are much more expensive than direct push. There is thus a technology- and cost-driven data gap. Appendix A describes the conditions encountered.

Three scenarios could account for the greater concentration of TCE observed in basalt compared to the Hanford Formation:

- The first is that a source contributes directly to basalt in areas where there is no alluvial aquifer and that TCE found in the alluvial aquifer is the result of small, scattered sources.
- The second and third scenarios involve differences in groundwater flow velocities. Groundwater velocities derived from aquifer hydraulic properties presented in

³ As described in appendix D, USACE and USEPA agreed on a conservative soil vapor screening program to determine whether a shallow soils compound was a potential source to groundwater. If a vadose zone contaminant at a given PSA was *not* detected in downgradient groundwater, and the "equilibrium" soil concentration is at least two orders of magnitude lower than the MTCA Soil Cleanup Level for Protection of Groundwater, then it could be eliminated as a potential source of contamination for that PSA. However, if a vadose zone contaminant at a given PSA *was* detected in downgradient groundwater, and the "equilibrium" soil concentration is at least three orders of magnitude lower than the MTCA Soil Cleanup Level for Protection of Groundwater, then it could be eliminated as a potential source of contamination for that PSA. Thus, TCE was retained at PSA 20 using the three orders of magnitude rule, [57 > 53 ppb(v)] and because of elevated downgradient TCE concentrations.

section 1.4.4 illustrate the wide range of transport rates in the alluvial and basalt aquifers. One consequence of the differences in groundwater velocity is that bodies of water in adjacent strata may be of significantly different age. Combined with unknown amounts of vertical transport between aquifers, the concentration of TCE in an aquifer at a given location probably reflects contributions from sources of different age and strength. Thus, TCE in faster moving groundwater in the Hanford Formation may reflect recent source contributions to groundwater, whereas the slower moving groundwater in basalt aquifers may be representative of source contributions from years ago.

- Finally, if sources exist in both alluvial and basalt aquifers, slower moving groundwater in basalt will be in contact with the source(s) for longer periods, allowing more TCE to go into solution. With short residence times in contact with the source(s), alluvial groundwater would be expected to contain lower TCE concentrations.

Because known concentrations of TCE in Roza 2 are of similar magnitude to those in Priest Rapids and Roza 1, Roza 2 may have its own sources (e.g., NAPL that has migrated down from Roza 1) or it may be receiving dissolved TCE, a source in Roza 1, through the dense flow interior. For the latter to be true, there must be good communication between the aquifers and relatively little dilution as downward migrating contaminated groundwater mixes with Roza 2 groundwater. As noted in section 1.4.3, vertical hydraulic connectivity between the Priest Rapids and Roza 1 flow-top appears to permit admixture of dissolved plumes between these basalt aquifers. Faulty grout seals in deep water supply wells might enhance downward communication, but current contaminant distribution implies natural conduits are primarily responsible, not manmade ones. Large water supply wells may have influenced the rate of migration, though, by enhancing head differences between shallow and deep basalt aquifers. As far as the potential for NAPL sources within Roza 2 goes, groundwater concentrations are not nearly high enough to imply the existence of NAPL in Roza 2.

Aerobic conditions, which inhibit anaerobic breakdown of TCE, are widespread at nearly all locations in all aquifers investigated. Therefore, reductive dechlorination does not appear to be influential on reducing TCE concentrations in groundwater. Exceptions to this statement occur in basalt aquifers downgradient of Site 28 (Tetraethyl Lead Disposal Site) and Site 21 (LMWTP). Cis-1,2-DCE, an anaerobic degradation product of TCE, is found in 04-BW06 and 99-BW15 at concentrations of 3-4 µg/L. Although conditions appear to be aerobic at each of those locations, there may be anaerobic conditions upgradient of 99-BW15 associated with biological activity in effluent from the treatment plant. These limited occurrences, apparently indicating anaerobic degradation of TCE, suggest that remedial actions involving enhancement of anaerobic conditions in the aquifers may achieve some level of degradation of TCE.

1.5.4 Identification of Preliminary AOPC

Preliminary AOPC in groundwater are identified in this section of the FS based on historical exceedance of the TCE MCL of 5 µg/L in the Priest Rapids-Roza 1 or Roza 2 aquifers. In chapter 2, the AOPCs will be refined based upon information from the review of applicable, relevant, and appropriate legal requirements. These preliminary AOPCs can be visualized as extending from ground surface down to a depth (at least) corresponding to the dense flow interior of Roza 2. Within these areas it should be recognized that not all groundwater

encountered will necessarily be contaminated. In nearly all instances, alluvial groundwater is believed to be free of contamination exceeding the TCE MCL. Similarly, it should also be recognized that contamination might exist outside of these AOPCs in any of the aquifers investigated. Professional judgment serves to minimize the likelihood that areas of the Priest Rapids-Roza 1 and Roza 2 aquifers outside of the identified AOPCs have contamination greater than the MCL. However, due to limitations on depth of investigation, there is uncertainty about whether contamination has migrated deeper than Roza 2. This uncertainty should be factored into any remedial actions contemplated for affected aquifers.

Because the existing monitoring well network has few wells in close proximity to the suspected source areas, concentrations of TCE used to define the AOPCs may understate the maximum impact to groundwater in those source areas. An additional factor that may lead to underestimation of maximum concentrations is that many groundwater grab samples taken during drilling in the latest investigation (see appendix A) were apparently diluted by water added during drilling. In instances where an accompanying well was not installed to confirm grab sample results, results obtained during drilling may represent the minimum of actual groundwater concentrations.

The three preliminary groundwater AOPCs with historical exceedance of 5 µg/L TCE are shown on figure 1.5-3. Data on which these AOPCs and the plume distribution map are based are presented in table 1.5-2. The vertical extent of contamination in these AOPCs can be seen in cross sections in figures 1.5-4 through 1.5-7. For section locations, refer to figure 1.4-3. The AOPCs are as follows:

- Preliminary AOPC 1 is defined based on contamination detected in the Priest Rapids-Roza 1 aquifer(s) extending from Site 20 (South Base Dump) south-southwest to the Skyline area. The Roza 2 aquifer is also considered to have TCE contamination beneath this entire area based on limited characterization. Portions of the alluvial aquifer (Hanford Formation) contain TCE but do not exceed the MCL. Occurrence of TCE in the Ringold Formation has not been fully characterized. Maximum concentrations are found in the Priest Rapids at 04-CW05 (88.3 µg/L in a grab sample taken during drilling) and monitoring well 04-BW09 (77.3 µg/L). A grab sample during drilling at 04-BW09, at a depth of 169 ft bgs (near the top of Roza 1), contained 61.6 µg/L. Aside from this Roza 1 grab sample, no data are available for TCE concentrations in the lower part of the Priest Rapids-Roza 1 aquifer near the head of the plume. Given that groundwater flow directions on the western side of Moses Lake are apparently towards the lake, the occurrence of low levels of TCE in ML-19 is believed to be unrelated to the Site. Roza 2 contains up to 29.6 µg/L at monitoring well 04-CW05 (see table 1.5-4). Areal extent of the contaminated groundwater plume in AOPC 1 is estimated at 26,000,000 square ft (0.93 square miles, 600 ac), although the extent exceeding the MCL is probably no greater than 16,000,000 square ft (0.57 square miles; 370 ac). It should be recognized that the 5 µg/L isopleth is not well constrained by monitoring well data along the downgradient margins, which adds uncertainty that should be addressed in remedial design.
- Preliminary AOPC 2 is defined based on contamination detected in the Priest Rapids-Roza 1 aquifer(s) extending from a broad area encompassing several dump sites (Sites 8,

31, and 33) near the southern end of the southeast runway to the south-southwest almost to the North Cascade Valley area. The Roza 2 aquifer is also considered to have TCE contamination beneath this entire area based on limited characterization. Contamination exists within parts of the Hanford Formation aquifer, and exceedance of the TCE MCL has been noted (in 00-AW11, which straddles the Hanford and Ringold). Aside from 00-AW11, extent of TCE in the Ringold Formation has not been characterized. Highest concentrations are found in Roza 1 at 91-BW03 (41.4 µg/L), with lesser amounts in Priest Rapids (00-BW12 at 24 µg/L) and Roza 2 (04-CW03 at roughly 23 µg/L). Areal extent of the contaminated groundwater plume in AOPC 2 is estimated at 52,000,000 square ft (1.9 square miles; 1,200 ac), although the extent exceeding the MCL may be as little as 14,000,000 (0.50 square miles; 320 ac). It should be recognized that the 5 µg/L isopleth is not well constrained by monitoring well data downgradient of 04-BW06, which adds uncertainty that should be addressed in remedial design. The only well between 04-BW06 and the domestic wells in North Cascade Valley is 99-BW12 (an uppermost Priest Rapids aquifer well). Given the unusually thin nature of the Priest Rapids aquifer and apparently competent dense flow interior beneath the aquifer at that location, the TCE concentration of 2.1 µg/L at 99-BW12 may not be representative of the entire Priest Rapids-Roza 1 aquifer and may understate maximum concentrations.

- Preliminary AOPC 3 is defined based on contamination detected at several locations (99-BW16, 04-BW04, and 04-BW05) in the Roza 1 aquifer, with relatively limited areal extent south of the Airport terminal. The Priest Rapids pinches out in this area and is not known to be contaminated. The Roza 2 aquifer is contaminated beneath this area; however, concentrations of TCE are apparently below the MCL. The alluvial aquifer in this area is restricted to the Ringold, and alluvial TCE concentrations do not exceed the MCL. Concentrations of TCE at 99-BW16 hovered around 5 µg/L until as recently as January 2001, but have dipped below since then (not detected at 2.3 µg/L in August 2004). Concentrations of TCE at 04-BW04 (2.47 µg/L) and the uppermost two of three low-flow samples (2.29 and 2.35 µg/L) at 04-BW05—are also below the MCL. With the exception of the deepest sample (6.06 µg/L) at 04-BW05, there are no exceedances of the MCL in the Roza 1 aquifer. Stratification of TCE in the aquifer at 04-BW05 adds uncertainty to the characterization of this aquifer in general. Areal extent of the contaminated groundwater plume in AOPC 3 is estimated at 10,000,000 square ft (0.36 square miles; 230 ac). This area is retained for evaluation in chapter 2 once PRAGs are determined for the Site.

Based on plumes defined in figure 1.5-3, total areal extent of contaminated groundwater is approximately 3.2 square miles. Area affected by TCE contamination above the MCL is estimated at 1.1 square miles.

Using simplifying assumptions about contaminant plume dimensions, average porosity, and average contaminant concentration, the mass and volume of dissolved-phase TCE in the two basalt aquifers in the AOPCs have been calculated (table 1.5-3). Roza 2 plume footprints are assumed equivalent to those of the Priest Rapids-Roza 1 aquifer in each AOPC. Because there is little evidence to suggest that TCE contamination is widespread, or at significant concentrations, within the alluvial aquifer, this aquifer has been excluded from the calculation. Total amounts of TCE for the plumes and AOPCs translate to approximately 158 kg or 108 L (28 gallons).

Suspected historic surface soil PSAs for TCE to groundwater were identified using a weight-of-evidence approach that factors in available data for the Site. The following criteria are used to identify areas where releases may have occurred:

- Persistent TCE in soil gas.
- Groundwater contamination in alluvium beneath, or immediately downgradient of, the PSA.
- Groundwater contamination in basalt aquifers beneath, or immediately downgradient of, the PSA.

Meeting all these criteria suggests a PSA or group of PSAs may have had a combination of frequency and quantity of release sufficient to transport TCE to the aquifers. This is not to say that there were no other discharge points for TCE; merely that their effect is likely to have been attenuated over the years to the point that ongoing problems are not evident. Also, identification of these suspected historical soil PSAs should not be taken to imply that surface or shallow subsurface soil sources continue to exist today. Rather, it appears from dissolved TCE hotspots in groundwater that current sources are located beneath these PSAs, either in deep vadose zone soils or in the aquifers themselves. Suspected historical surface source areas for the three AOPCs are as follows:

- AOPC 1 - Site 20 (South Base Dump).
- AOPC 2 - Site 8 (Randolph Road Base Dump), Site 31 (19th Avenue Base Dump), and Site 33 (Dump at the end of the southeast runway).
- AOPC 3 - Numerous, may have included Site 3 (Aircraft Wash Rack), Site 16 (Engine Rebuilding Facility), Site 23 (Engine Buildup Facility), and Site 25 (Building 408).

Based on comments on the Draft GWFS received from USEPA, all or part of the contamination in AOPC 3 may be accounted for by an alternative hypothesis involving the influence of historical extraction at the CML water supply wells ML-21, -22, and -23. Before rehabilitation of ML-21 and decommissioning of ML-22, extraction may have drawn contaminated groundwater westward from the plume originating near the end of the runway. The existing TCE contamination may be a remnant part of the plume that has not flushed through the aquifer in the years since.

A source for the northeastern-most extent of AOPC 2, centered around 99-BW15, has not been identified based on the criteria listed above. The only plausible PSAs upgradient of this area are Sites 6a (the Base Closure Landfill), 6b (the Dumpster Wash Area), and 21 (LMWTP). A combination of weak TCE soil gas signatures and lack of alluvial and basalt aquifer contamination in the vicinity of these sites makes pinpointing a source difficult.

Because not all PSAs were investigated to the same extent during the RI/BRAs and follow-on NEI, some uncertainty remains about the seriousness of impact to groundwater. A case in point is Site 11, one of the fire training area burn pits. Investigation at Site 11 was limited to soil sampling, soil vapor sampling, and groundwater sampling of a downgradient alluvial

monitoring well. Soil gas and groundwater data imply that TCE was introduced to the environment at Site 11 (perhaps the adjoining Site 9, as well). However, no basalt wells exist in the area to indicate more extensive impact. Given the weakness of TCE signatures in soil gas and alluvial groundwater above significantly affected basalt aquifers in other parts of the study area, questions remain about the magnitude of TCE contamination problems beneath and downgradient of Site 11.

Another PSA with some uncertainty associated with it is the LOX Plant (Site 19). Of all identified PSAs, Site 19 was the only site where highly contaminated liquids and significant levels of TCE in soil gas affecting a broad area were discovered. The contaminated liquids were contained in underground vaults that were part of an industrial waste disposal system. Since removal of the vaults, TCE soil gas has shown marked attenuation, implying that the vaults themselves (with contaminated liquids) were the primary source of TCE in soil gas. Despite evidence that the waste disposal system was designed to ultimately discharge liquids to the subsurface, groundwater beneath and immediately downgradient of the Site shows no clear evidence that TCE releases beyond those previously investigated and removed presently affect the environment.

1.6 BASELINE RISK ASSESSMENT SUMMARY

The RI/BRA report (MWH, 2003) was supplemented to include unrestricted future (residential) use for some of the surface-soil PSAs (MWH, 2004a). Only TCE and acetone were found above screening levels.

1.6.1 Groundwater Risk Assessment

The RI/BRA and Supplemental Risk Assessment Report (MWH, 2004) identified potentially exposed populations. Risks were estimated based on current and future land uses for the Site. The land uses were as defined in the *Grant County Long Range Plan* (Grant County, 1994b). Consistent with this Plan, PSAs were segregated into two groups:

- PSAs associated with a future “commercial/industrial” land use area, comprised of the GCIA, and associated industrial facilities.
- PSAs associated with future “residential” land use area comprised of residential, rural agricultural, and commercial areas located south of the former LAFB.

These functional land use categories were also used to evaluate exposures to groundwater by both future residential and future commercial/industrial receptors, consistent with MTCA Method A regulation and USEPA policy. Specifically, with reference to the latter, the role of the baseline risk assessment is to address the risk associated with a site in the absence of any remedial action or control, including institutional controls (ICs).

All groundwater in the State of Washington is considered a potential drinking water resource. Therefore, an unrestricted drinking water scenario was also evaluated for all land use areas.

For each preliminary COPC, an estimation of the contaminant concentration within each PSA was developed. These values are referred to as exposure point concentrations (EPC). EPCs for

PSAs were based on the maximum or 95 percent upper confidence limit on the mean concentrations of COPC detected in soil or soil gas samples collected to a maximum depth of 15 ft bgs. EPCs for groundwater were based on the maximum or 95 percent upper confidence limit on the mean concentrations of COPC detected in individual wells, or well clusters, representing the Hanford and Ringold Formation, or the Priest Rapids Member and the Roza 1 Flow. Well clusters (figure 1.6-1) were identified for grouped monitoring wells that appear to represent contamination from a common source of TCE and/or share common transport pathways. Three well clusters were identified as follows:

- Priest Rapids Cluster #1, wells downgradient of Site 20 (99-BW18 and 99-BW10).
- Roza 1 Flow Cluster #1, wells downgradient of Sites 33, 21 and 8 (91-BW03, 92-BW01, 99-BW01, 99-BW15 and 02-BW02); Roza Cluster #1 was further segregated because of uncertainties regarding potential sources and transport mechanisms in the vicinity into:
 - Roza Cluster #1a (91-BW03, 92-BW01 and 99-BW01).
 - Roza Cluster #1b (99-BW15 and 02-BW-02).
- Drinking Water Supply Well Cluster #1 (WP-15E and WP-15W).

These well clusters were initially identified based upon an assumption that the Priest Rapids and Roza 1 flows act as a single hydrologic unit. This agrees with current CSM. To assess risks associated with this hypothesis, well clusters or individual wells were merged into a combined Priest Rapids-Roza 1 Flow hydrologic unit. EPCs for well clusters were based on the maximum, or 95 percent upper confidence limit on the mean, concentrations of TCE for the grouped data. Table 1.6-1 shows the risk values associated with the combined Priest Rapids-Roza 1 aquifers. EPCs for individual wells were based on maximum detected concentrations of TCE or other COPC.

The results of screening for COPC in groundwater indicated that TCE concentrations measured in the Hanford and Ringold Formations were below the screening criterion of 5 µg/L. One exception to this is in monitoring well 00-AW11 located in the central portion of the study area, which was slightly above the screening criterion. Other chemicals exceeding screening criteria in alluvium groundwater included two trihalomethanes (bromodichloromethane and dibromochloromethane) in monitoring well 91-AW14 and two petroleum-related compounds (1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene) in monitoring well 91-AW15. The two trihalomethanes, bromodichloromethane and dibromochloromethane, were detected in drinking water well WP-13E at concentrations above their respective screening criteria. Maximum concentrations of TCE exceeded its screening criterion in four wells screened in the Priest Rapids Member (i.e., 99-BW10, 99-BW15, 99-BW18 and 00-BW12). Other chemicals exceeding screening criteria in the Priest Rapids Member included benzene (00-BW11), manganese (00-BW02, 00-BW12 and 00 BW13), and MTBE (at 00-BW18). Maximum concentrations of TCE exceeded its screening criterion in seven wells screened in the Roza Member (i.e., 91-BW03, 92-BW01, 99-BW01, 99-BW15, 99-BW16, 02-BW01 and 02-BW02). Maximum concentrations of MTBE (92-BW02) and acetone (02-BW02) in wells screened in the Roza Member also exceeded their respective screening criteria.

Data from wells screened in the Priest Rapids and Roza Members were also combined. Since COPC screening was performed on a well-specific basis, however, screening results for this combined unit are the same as those described above for the Priest Rapids and Roza Member wells.

Stratigraphic intervals for privately owned drinking water wells are generally not known. Therefore, drinking water wells were not assigned to a groundwater stratigraphic unit. Maximum concentrations of TCE exceeded the screening criterion in drinking water wells WP-14, WP-15E and WP-15W. However, wells WP-15E and WP-15W, which are adjacent to the Skyline Replacement well, can be more accurately determined than for other domestic wells. Based on the Skyline Replacement well, well WP-15E appears to be open to the Priest Rapids Member and the Roza 1 Flow. Well WP-15W appears to be open to the Roza 1 and Roza 2 Flows and possibly also the Priest Rapids Member.

All groundwater stratigraphic units were further evaluated in the Baseline Human Health Risk Assessment because they contained TCE and other COPC. See table 1.6-1. For all monitoring wells or well clusters evaluated in the Baseline Human Health Assessment, with the exception of monitoring well 02-BW02, carcinogenic risk and noncarcinogenic hazard estimates were within the USEPA's acceptable risk range of 10^{-6} to 10^{-4} and had a hazard index (HI) less than or equal to 1.0. In addition, these risk and hazard estimates were equal to or below the MTCA risk and hazard criteria of 1×10^{-5} and 1.0, respectively. The estimated noncancer HI (18) for monitoring well 02-BW02 was attributable to the presence of acetone at a concentration of 19 mg/L. Confirmation samples showed that the maximum detected concentration of 19 mg/L is an accurate measurement of acetone in well 02-BW02. The potential source of acetone in 02-BW02 is not currently known, but, as noted in section 1.5, the compound may have arisen from use of materials in well construction.

The risk assessment indicates that risks due to TCE in groundwater fall within the Superfund risk range of "acceptable risks" of 10^{-6} to 10^{-4} incremental lifetime cancers and does not indicate that a remedial action is required due to an exceedance of the 10^{-4} threshold. However, because TCE concentrations have exceeded Federal and State MCLs of 5 $\mu\text{g/L}$ in numerous wells, compliance with ARARs was evaluated.

As described in the RI/BRA, USEPA is currently in the process of finalizing a health effects reassessment for TCE. The draft document, Trichloroethene Health Risk Assessment: Synthesis and Characterization (External Review Draft) was published in the National Center for Environmental Assessment Database September 19, 2001. The USEPA's draft reassessment concludes that TCE exposure is associated with several adverse health effects including neurotoxicity, immunotoxicity, developmental toxicity, liver toxicity, kidney toxicity, endocrine effects, and several forms of cancer. In addition, the draft reassessment characterizes TCE as "highly likely to produce cancer in humans."

The RI/BRA used an oral reference dose of 6.0×10^{-3} mg/kg-d and a cancer slope factor of 1.1×10^{-2} (mg/kg-d) $^{-1}$. USEPA's (2001) draft reassessment proposed an oral reference dose of 3×10^{-4} mg/kg-d, and an inhalation reference concentration of 4×10^{-2} mg per cubic meter for the evaluation of noncarcinogenic health effects. A twenty-fold range of carcinogenic slope factors was proposed for evaluating carcinogenic risk, ranging between 2×10^{-2}

and $4 \times 10^{-1} \text{ mg/kg-d}^{-1}$. Because the proposed carcinogenic slope factors are higher than that used in the risk assessment in the RI/BRA, risk estimates for TCE could increase in the event that the revised TCE values are approved in the final guidance. Upon finalization of USEPA's peer review process for the toxicity reassessment for TCE, risks associated with TCE may be re-evaluated for the Site, as appropriate.

Section 1.5.1 above summarizes the SSFS assessment of compounds in soil that could affect future groundwater quality. The SSFS identifies means to address the potential impact of these compounds.

No completed pathways exist for groundwater exposure to ecological receptors in the RI/BRA. For this reason, no ecological assessment of those pathways was performed.

1.6.2 Surface Water Risk Assessment

Seep-related values of TCE and other chemicals have been negligible; hence, no human health assessment was done for surface water.

An ERA was conducted to evaluate the potential impacts of contaminants released from the Site on ecological habitats and receptors (i.e., plants or wildlife). The study area for the ERA included PSAs located within and adjacent to the boundaries of the former LAFB and areas hydraulically downgradient of the former LAFB that might have been impacted by COPC. The ERA included an assessment of the biological resources located in the vicinity of the Site and the selection of assessment and measurement endpoints for evaluation of potential impacts to ecological habitats and receptors. The quantitative ERA focused on terrestrial receptors potentially inhabiting or using the PSAs. Based on the nature of the contaminants, the results of the hydrostratigraphic model, and the low likelihood that significant concentrations of contaminants will migrate to surface water bodies in the vicinity of the Site, aquatic and riparian receptors inhabiting or using Crab Creek or Moses Lake were not quantitatively evaluated in the ERA.

The ERA concluded that potential impacts of TCE in groundwater on ecological receptors using Moses Lake are unlikely, given the volatility of this chemical, the tendency of TCE to be metabolized by plants and animals, and its low potential for bioaccumulation. The RI/BRA report noted, however, that some uncertainties exist regarding hydrological conditions in the northwestern portion of the Site due to a lack of monitoring wells in the alluvial aquifer in this area.

CHAPTER 2
RAOs, Regulatory
Requirements, and Identification
and Screening of Technologies

CHAPTER 2. RAOs, REGULATORY REQUIREMENTS, AND IDENTIFICATION AND SCREENING OF TECHNOLOGIES

2.0 INTRODUCTION

This chapter of the GWFS provides the regulatory basis and technical considerations used in the evaluation of potential remedial alternatives to address contaminant sources associated with the groundwater in the study area. Substances have been identified at the Site as “hazardous substances” as defined by CERCLA Chapter 101(14) (42 U.S.C. 9601(14)). CERCLA hazardous substances are “any pollutant or contaminant” that may present an imminent and substantial danger to public health or welfare as set forth in CERCLA Chapter 104(a)(1) (42 U.S.C. 9604(a)(1)). Section 1.5 described these substances in groundwater as COPC.

Objectives of chapter 2 are:

- Identify specific RAOs for the GWFS.
- Identify media to which remedial actions may apply, based on the RAOs.
- Identify and evaluate other requirements for consideration during preparation of the GWFS.
- Identify COCs and associated Preliminary Remedial Action Goals (PRAGs) for the GWFS.
- Develop GRAs for groundwater to address the RAOs.
- Screen technologies for these response actions.

In order to accomplish these objectives, regulatory conditions that affect the selection of alternatives first need to be explored.

2.1 REMEDIAL ACTION OBJECTIVES

RAOs are medium-specific goals designed to protect human health and the environment. In accordance with CERCLA, preliminary RAOs were developed earlier, during the RI/BRA, to focus the investigation on the constituents, media, pathways, and receptors of potential concern. Preliminary RAOs for the Site were presented in the TM on preliminary RAOs and alternatives: Site Characterization Technical Memorandum for the Moses Lake Wellfield Contamination Superfund Site (MWH, 2000).

During the FS stage of the RI/FS process, RAOs are refined to specify the remedial goals, constituents and media of concern, and potential risks to human health and the environment for

consideration during the evaluation of remedial alternatives. The RAOs are refined here based on findings and conclusions of the RI and more recent NEI. The consideration includes results of site investigations and human health and ERAs documented in the RI/BRA (MWH, 2003) and the *Final Supplemental Remedial Investigation Report* (MWH, 2004a). The following are RAOs for groundwater:

- RAO 1. Prevent human exposure to groundwater contaminated with contaminants of concern (section 2.2.1) above their respective PRAGs (see section 2.2.3).
- RAO 2. Minimize horizontal and vertical extents of groundwater contaminant plumes exceeding PRAG.
- RAO 3. Prevent or minimize further migration of contaminants from source materials to groundwater.

Achievement of RAOs is discussed in the following paragraphs and given more detailed treatment in chapter 4.

RAO 1 is similar to the "Overall Protectiveness" CERCLA criterion, and its being met is a threshold (i.e., pass/fail) condition for remedial alternatives.

Attainment of RAO 2 needs a means of measurement; otherwise, any reduction in extents will meet the RAO. The plume boundary is defined by the PRAG. To provide for measurable attainment of RAO 2, and to better distinguish it from RAO 3, this objective is further specified as follows. The reduced plumes should fall entirely within areas within which existing controls are protective of human health, i.e., areas in which potential exposures may be averted and areas where no residential habitation occurs, such as areas zoned commercial industrial or airport owned. When a plume's hotspot occurs outside of a commercial-industrial or airport-owned area, then attainment of RAO 2 would require secure control of exposures using alternate water supply, ICs, or other similar methods.

After realizing full completion of RAO 3 in conjunction with RAO 2, the aquifer would be returned to its highest beneficial use, which is the desired condition under the NCP. Due to our limited understanding of the precise locations of subsurface sources of TCE at the Site, it is possible that none of the remedial alternatives will fully achieve RAO 3; however, some of the alternatives may perform better at treating a source, should one be isolated. If not possible to treat a source, the time-scale of remediation may be extended; for example, active treatment may be required for a longer time. Physical locations to which the RAOs apply are presented in section 2.4.

2.2 IDENTIFICATION OF PRELIMINARY ARARs AND TBC GUIDELINES

Consideration of ARARs is required under 40 CFR 300.430(e)(2). Degree of cleanup may be based on ARARs as expressed under CERCLA section 121(d). This section identifies preliminary ARARs and TBC guidelines affecting prospective remedial actions in the Site. (USEPA will accomplish the final selection of these requirements and guidelines in the Proposed Plan and ROD, for those remedies that are selected.) Together, ARARs and TBC guidelines are the body of existing statutes, regulations, ordinances, guidance, and published reports pertaining

to any potential cleanup actions at the Site. ARARs and TBCs influence development of remedial alternatives through the establishment of numeric cleanup levels, site requirements, disposal, and operating parameters, or monitoring requirements.

The 40 CFR 300.5 defines key terms and provides guidance for selecting them at a specific site:

“Applicable requirements means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable.”

“Relevant and appropriate requirements means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not ‘applicable’ to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate.”

By letter of February 16, 2007, Washington Department of Ecology identified preliminary ARARs to USEPA.

ARARs are frozen when the ROD is signed to avoid continuing interruption, re-evaluation, and redesign during remediation. However, if a hazardous substance is left onsite above levels which allow for unrestricted use and unlimited exposure, the remedial action must be reviewed every 5 years. The 40 CFR 300.430(f)(1)(ii)(B)(1) states, “Requirements that are promulgated or modified after ROD signature must be attained (or waived) only when determined to be applicable or relevant and appropriate and necessary to ensure that the remedy is protective of human health and the environment.”

As described in the rule establishing the NCP (55 FR 8666), nonbinding and nonenforceable advisories and guidance are not ARARs. The preamble specifically states that several factors be considered in identifying relevant and appropriate requirements, including:

- Nature of the waste and its hazardous properties.
- Other site characteristics.
- Nature of the requirement.

In order for a requirement to be an ARAR per the definition in CERCLA and the implementing regulation, the NCP, all five of the following conditions must be met:

- It is promulgated.
- It is related to an environmental or facility siting law.
- It is substantive (as opposed to administrative or procedural in nature; see below).
- It is either applicable or relevant and appropriate.
- It is a cleanup standard, standard of control, or other substantive requirement that specifically addresses a hazardous substance, pollutant or contaminant, remedial action, location, or other circumstance found at a CERCLA site (e.g., ARARs are not identified for offsite actions such as transportation of waste.)

According to EPA (1988a, CERCLA Compliance with Other Laws Manual, Volume 1):

“Substantive requirements are those requirements that pertain directly to actions or conditions in the environment. Examples of substantive requirements include quantitative health- or risk-based restrictions upon exposure to types of hazardous substances (e.g. MCLs establishing drinking water standards for particular contaminants), technology-based requirements for actions taken upon hazardous substances (e.g. incinerator standards requiring particular destruction and removal efficiency), and restrictions upon activities in certain special locations (e.g. standards prohibiting certain types of facilities in floodplains).

“Administrative requirements are those mechanisms that facilitate the implementation of the substantive requirements of a statute or regulation. Administrative requirements include the approval of, or consultation with administrative bodies, consultation, issuance of permits, documentation, reporting, recordkeeping, and enforcement. In general, administrative requirements prescribe methods and procedures by which substantive requirements are made effective for purposes of a particular environmental or public health program.”

Some information that is neither law nor regulation may be identified as constituting TBC. TBC includes “other information” that does not meet the definition of an ARAR, but may be necessary to determine what is protective or may be useful in developing Superfund remedies. Criteria, advisories, or guidance developed by the USEPA, other Federal agencies, or States, may assist in determining, for example, health-based levels for a particular contaminant for which there are no ARARs of the appropriate method for conducting an action. The TBC generally fall into the following three categories:

- Health effects data with the highest degree of credibility.
- Technical information on how to perform or evaluate site investigations or response actions.
- Policy (e.g., State or Federal groundwater policy).

ARARs may affect site cleanup actions for several different reasons. Laws that regulate the concentrations of hazardous substances present at the Site are referred to as chemical-specific requirements. Other laws may be applicable, because they establish standards for the type of cleanup action that may be implemented (e.g., drinking water standards) or for the general site setting (e.g., shoreline protection requirements). These latter items are referred to as action-specific and location-specific requirements.

2.2.1 Chemicals of Concern

In this section, COPCs are refined to COCs, which will be subjected to ARARs analysis. Potential receptors, based on the CSM contained in the RI/BRA report and Baseline Risk Assessment (MWH, 2003a), are consumers of groundwater; there is no substantial release of TCE-to-surface water. The potential current and future exposure pathways include groundwater used as a current or potential future drinking water source. The compounds that were determined to be COPC in section 1.5.1 are listed further below. Compounds for which soil-to-groundwater is estimated as the chief source are shown separately from those currently detected in groundwater⁴. These are chiefly included in the GWFS, because they may become part of the monitoring that is triggered by the SSFS determinations.

- TCE is retained as a wide-scope groundwater COC.
- Manganese was never seen to be associated with a HI of greater than 1, although at monitoring wells 00-BW02 and 00-BW13, manganese slightly exceeded the secondary MCL of 0.05 mg/L (table 1.6-1). Secondary MCLs are not ARARs, as described in section 2.2.2.1, and the risk is at acceptably low levels from it; therefore, manganese is eliminated from the COC list.
- Of the remaining compounds, acetone is a narrow-scope COC.
- The SSFS deals further with actions to remediate groundwater impacts from surface soil COC.

2.2.2 Identification of Potential Chemical-Specific, Action-Specific, and Location-Specific ARARs and TBCs

Tables 2.2-1, 2.2-2, and 2.2-3 identify Federal, State, and local legislation and implementing regulations as potential ARARs and TBCs. The potential ARARs and TBCs are described below, in the order in which they appear in these tables.

2.2.2.1 Federal Safe Drinking Water Act (SDWA)

The Federal SDWA of 1974, as amended, is the primary Federal legislation protecting drinking water supplied by public water systems. This act establishes primary regulations for the protection of the public health and secondary regulations relating to the taste, odor, and appearance of drinking water.

⁴ As noted in section 1.5, one site, Pumphouse 1, does have petroleum chemicals in groundwater above levels of concern but is already subject of an ongoing cleanup with the Washington Department of Ecology.

CERCLA, Chapter 121, specifies procedural requirements for identification of hazardous substances left onsite at the conclusion of remedial actions. While not listed as an ARAR, it is discussed in this section as it clarifies applicability of other laws. CERCLA states that the action requires a level or standard of control, which at least attains applicable or relevant and appropriate Federal or State environmental or public health requirements, except in certain limited circumstances. USEPA's policy is to attain ARARs and TBCs necessary for protection, pertaining either to contaminant levels or to performance or design standards to ensure protection at all points of potential exposure.

The NCP (40 CFR 300.430(a)(1)(iii)(F)), which provides the regulatory framework for the Superfund program, states "EPA expects to return usable groundwaters to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site."

The NCP, at 40 CFR 300.430(e)(2)(i)(A)(5) states the following (underlines added):

"(B) Maximum contaminant level goals (MCLGs), established under the Safe Drinking Water Act, that are set at levels above zero, shall be attained by remedial actions for ground or surface waters that are current or potential sources of drinking water, where the MCLGs are relevant and appropriate under the circumstances of the release based on the factors in Sec. 300.400(g)(2). If an MCLG is determined not to be relevant and appropriate, the corresponding maximum contaminant level (MCL) shall be attained where relevant and appropriate to the circumstances of the release.

"(C) Where the MCLG for a contaminant has been set at a level of zero, the MCL promulgated for that contaminant under the Safe Drinking Water Act shall be attained by remedial actions for ground or surface waters that are current or potential sources of drinking water, where the MCL is relevant and appropriate under the circumstances of the release based on the factors in Sec. 300.400(g)(2)."

The MCLG is a nonenforceable level, based on possible health risks and exposure. USEPA has not determined the MCLG as feasible or cost-effective, so it has not been established as an MCL. For TCE, the MCLG was set at zero as USEPA deems this level of protection would best prevent potential health problems associated with exposure to TCE. USEPA has set an enforceable standard, which is the MCL, as the primary drinking water standard. The TCE MCL was set at 5 µg/L because USEPA has determined that this concentration is the lowest level to which water systems can reasonably be required to remove this contaminant should it occur in drinking water given present technology and resources. In the Federal SDWA, all public water supplies (those serving more than 25 people) must abide by the SDWA regulations. The TCE MCL is a chemical-specific applicable requirement for Site groundwater withdrawn into public water distribution systems and supplies (see section 2.2.2.3).

Secondary MCLs are federally-established, nonenforceable drinking water standards based on aesthetic qualities instead of human health protection; they are not promulgated and, hence, are not ARARs.

All groundwater in the Site is considered potable. Thus, under the SDWA, the TCE MCL of 5 µg/L is an applicable, chemical-specific requirement.

2.2.2.3 Public Water Supply Systems

WAC 2446-290, Public Water Supplies (Group A Public Water Systems), and WAC 246-291, Group B Public Water Systems, defines procedural regulatory requirements to protect the health of consumers using public drinking water supplies. Group A and B systems and some related terms are described in WAC 246-290-020.

- Group A systems are those that regularly serve 15 or more residential connections or 25 or more persons per day for more than 60 days per year. There can be community (15 or more year-round residents) and noncommunity systems (serve fewer or for less time).
- Group B systems are those that regularly serve less than 15 residential connections or fewer than 25 persons per day for more than 60 days per year.

This code is an administrative regulation affecting purveyors of water. It specifies compliance of proposed water supply systems to include the secondary MCL for Group A and B public water systems. For example, WAC 246-291-100 states, "The owner" of a Group B system "shall ensure that drinking water is obtained from the highest quality source feasible. Existing sources shall conform to the primary water quality standards established in this chapter. Proposed sources shall conform to the primary and secondary water quality standards established in this chapter and the well construction standards established under chapter 173-160 WAC."

The following section states that analysis for other substances such as TCE may be required by the State (or implementing county), and that thus authority exists to require testing of Group B systems:

"WAC 246-291-350 (Other substances).

"(1) In areas known or suspected of being contaminated with other substances of public health concern, the department may require that an owner submit water samples to test for the suspected contamination at a frequency determined by the department.

"(2) The department may require repeat samples for confirmation of results.

"(3) Any substance confirmed in a water system that does not have an MCL listed in this chapter shall be subject to the MCLs...and other provisions found in chapter 246-290 WAC."

For single-family residences and systems serving less than five residences on the same system, neither the primary nor the secondary MCL would be a chemical-specific applicable requirement (table 2.2-4).

These requirements are neither applicable nor relevant and appropriate for the selection of a remedy. However, should a selected remedial option be to provide a new Group A water supply,

then this regulation could be action specific (table 2.2-2). This Act could also be an action-specific requirement for onsite point-of-use well-head filters or provision of bottled water as a short-term remedy to a number of people corresponding to a Group A or B supply population.

2.2.2.4 *Federal Clean Water Act*

The Clean Water Act (Federal Water Pollution Control Act, 33 U.S.C. 1251 – 1376, as amended) regulates discharges and impacts on “Waters of the United States” which includes waterways and wetlands. It establishes surface water quality criteria in Chapters 303 and 304. Since groundwater, based upon information in the RI/BRA, is not believed to be impacting surface water, it is not applicable to the groundwater medium in a chemical-specific sense. Furthermore, it is unlikely that selected remedy or remedies for groundwater contamination would involve discharge of water to a surface water body; therefore, the Act would likely not be a relevant and appropriate action-specific requirement. Ambient Water Quality Criteria are not promulgated in the Clean Water Act, and hence are not chemical-specific ARARs in accordance with this law. (See section 2.2.2.5, however.)

2.2.2.5 *Water Quality Standards for Surface Waters in the State of Washington*

This State regulation (WAC 173-201A) adopts and promulgates the Ambient Water Quality Criteria, and the National Toxics Rule (40 CFR 131.36), which could apply only if groundwater were to discharge contaminants into surface water above the listed levels. For TCE, the water quality standard for organisms-only consumption for protection of human health is 81 µg/L, which is higher than nearly all groundwater concentrations found in the AOPCs, at a distance from Moses Lake and Crab Creek, with intervening lower concentrations. As concluded in the RI/BRA, there is no current affect of TCE on surface water. Ambient Water Quality Standards are neither ARAR nor TBC.

2.2.2.6 *Water Quality Standards for Groundwaters in the State of Washington*

The WAC 173-200 specifies means to protect groundwater by determining methods to prevent intrusion of contaminants. However, the regulation specifically excludes CERCLA actions, and hence is neither applicable nor relevant and appropriate.

2.2.2.7 *Washington MTCA*

Washington State legislation for the investigation and cleanup of a release of a hazardous substance is MTCA (WAC 173-340). MTCA governs releases at all facilities in the State of Washington and defines three types of cleanup standards: Methods A, B, and C. Method A defines cleanup levels for 25 of the most common hazardous substances (including TCE) found at contaminated sites and is designed for cleanups that are simple, involve a few hazardous substances, or do not warrant risk assessments and site studies. Method B sets levels using a site risk assessment. Method C levels are only used on qualifying industrial properties if Method B levels are technically impossible to achieve, lower than background levels, or may cause more environmental harm than good.

The act states that cleanup actions approved by Ecology under the MTCA chapter 70.105D Revised Code of Washington, or by USEPA under CERCLA shall include groundwater cleanup standards developed under WAC 173-340-720. Therefore, the applicability of the act is dependent upon a decision for cleanup requiring establishment of cleanup levels.

Method A includes a list of promulgated cleanup standards (WAC 173-340-900, Tables 740-1 [residential], 745-1 [industrial], 749-3 [ecological]). Site cleanups that achieve Method A cleanup levels may be used without future restrictions on property due to residual levels of contamination, except in instances where ICs are required.

Method B does not include a promulgated list, but instead defines procedures to follow by equations. Method B is divided into two tiers. Tier I uses generic default assumptions to calculate cleanup levels. Tier II provides for the use of chemical-specific or site-specific information to modify the default assumptions. For individual carcinogens, the upper bound for the excess lifetime cancer risk is set at 10^{-6} , or 10^{-5} for multiple hazardous substances or pathways. For individual or multiple noncarcinogenic compounds, the bound is set as a HI of 1 or less for hazardous substances with similar noncarcinogenic toxic effects and no significant adverse effects on the propagation of aquatic or terrestrial organisms. Except where ICs are required, site cleanups that achieve Method B cleanup levels may be used without future restrictions on property due to residual levels of contamination. Method B includes calculation of soil values sufficient to protect leaching to groundwater from contamination above Method B ingestion values.

Method C does not include a promulgated list, but instead defines procedures to follow by equations. This method can be used to establish surface water, groundwater, or air cleanup levels or industrial soil or industrial air cleanup levels at industrial properties. It is likewise divided into two tiers. Tier I uses generic default assumptions to calculate cleanup levels. Tier II provides for the use of chemical-specific or site-specific information to modify the default assumptions. For individual and multiple carcinogens, the upper bound for the incremental lifetime cancer risk is set at 10^{-5} . For individual or multiple noncarcinogenic compounds, the bound is set as a HI of 1 or less for hazardous substances with similar noncarcinogenic toxic effects and no significant adverse effects on the propagation of aquatic or terrestrial organisms, or an exclusion must be established. ICs are required for cleanup sites using Method C.

Methods A, B, and C are Washington State regulations; therefore, they cannot be applicable under CERCLA, but they may be relevant and appropriate requirements or TBC guidance. Methods B and C are administrative procedures and not substantive, hence, are TBC. MTCA A for TCE is equal to the Federal (and State) MCL. To be relevant and appropriate, a State standard must be less than the Federal standard. Therefore, MTCA A is TBC for this compound.

For acetone, there is no Method A value; a Method B value was calculated: 7.2 mg/L. As stated, this is based on TBC.

2.2.2.8 *Resource Conservation and Recovery Act (RCRA) and the Washington Underground Injection Control Program*

RCRA (40 CFR 260-268) covers the generation, transport, storage, treatment, and disposal of hazardous waste. In Washington, most RCRA authority has been delegated to Ecology, and is implemented through the Dangerous Waste Regulations (WAC 173-303). Discussion of the Washington State Dangerous Waste Regulations is presented below. Potential chemical-specific requirements include characteristic waste levels; however, these are much higher than any of the concentrations of TCE or other groundwater chemicals found to date in the Site. In addition, listed wastes have not been identified at the site. Therefore, this is not relevant and appropriate; but it could be should future discoveries of highly concentrated in groundwater sources occur and should the materials be generated by removal.

As it relates to **offsite** disposal of wastes derived from site-related cleanups, RCRA would not be an applicable action-specific requirement. It would be applicable in the unlikely case that a waste, e.g., a sorbent be used to remove TCE from groundwater, were to be proposed for onsite disposal. As described in the following paragraph, the Underground Injection Control Program (WAC 173-218) would be applicable if treated water were to be placed into the ground. RCRA Chapter 3020 is applicable to re-injection as part of a CERCLA response action of *contaminated* groundwater into an underground source of drinking water. This program is administered by Ecology. See also section 2.2.2.3, Water Quality Standards for Groundwaters in the State of Washington.

The NCP (at 40 CFR 300.440) requires offsite storage, destruction, treatment, or secure disposition of hazardous substances from Superfund sites to be carried out only at hazardous waste disposal facilities that are in compliance with Subtitle C of Federal RCRA. Compliance with the "CERCLA offsite" rule is a procedural requirement under the citation but is neither an ARAR nor TBC.

2.2.2.9 *Washington Dangerous Waste Regulations*

The regulation contains a series of mostly administrative rules relating to aspects of generation, handling, storage, and disposal of dangerous waste. If wastes are managed onsite, WAC 173-303 substantive requirements (e.g., definitions of dangerous waste used for identification) pertaining to dangerous waste generation, handling, and storage would be potentially relevant and appropriate.

2.2.2.10 *Controls for New Sources of Toxic Air Pollutants*

This regulation addresses air quality issues associated with emissions of toxic air pollutants. TCE is a State Class A toxicant for which emission limits are published. WAC 173-460-030(b)(iii)(B) states that sites subject to WAC 173-340, the MTCAs, are also subject to WAC 173-460. The Best Available Control Technology for Toxics (T-BACT) for TCE emissions could be an action-specific requirement should the remedy include emissions of TCE to ambient air.

2.2.3 Preliminary Remedial Action Goals

COCs are linked to PRAGs by comparison to risk information and ARARs. The PRAGs become the basis for identifying a need for, and the efficacy of, various remedial options. The PRAGs and their regulatory basis are shown in table 2.2-4.

As summarized in section 1.5.1, for the Site as a whole, the groundwater COCs were reduced to two compounds: TCE and acetone. Note that surface soil compounds that are estimated to potentially affect groundwater in future are described in appendices C and D, but further evaluated in the SSFS. The following discussion targets the groundwater COC.

Table 1.6-1 shows that acetone levels exceeded an HI of 1.0, with a concentration of 19 mg/L at well 02-BW02, downgradient of PSA 21 (WWTP). This was the only detection of acetone during any of the sampling events between November 1999 and October 2002. While acetone is a common laboratory contaminant, it is unusual for it to be detected at such a high level and in only one well of several in the area. Monitoring well 02-BW02 was sampled in February 2003 to confirm the acetone detection, since acetone was detected at 17 and 19 mg/L in the primary and duplicate samples. Acetone in well 02-BW02 is suspected to be a product of breakdown of isopropanol thought to have been present in the clay sealant used during well construction. The drinking water concentration of acetone that generates a HQ of 1.0 is 7.2 mg/L using the equation in MTCA (720-1, Noncarcinogenic Compounds). It is expected that future monitoring at this well may indicate that acetone is no longer above this value. If, however, it should remain above 7.2 mg/L, a remedy is required, and the MTCA B value of 7.2 mg/L would become applicable for this well.

TCE contributes to summary incremental lifetime cancer rates of $>10^{-6}$ at several wells, as shown in table 1.6-1. TCE exceeded the MCL of 5 $\mu\text{g/L}$ at a large number of wells.

2.2.4 Areas to Which RAOs Apply

2.2.4.1 Area or "Footprint"

This section refines the preliminary AOPCs described in section 1.5.4. Since TCE drives the determination of the AOPCs, AOPCs 1 and 2 are carried forward because of significant exceedance of the MCL. AOPC 3 is not carried forward, although there was a marginal exceedance of the MCL, 6.06 $\mu\text{g/L}$ at 04-BW05 in AOPC 3. As noted in section 1.5, not all groundwater in the "footprint" of these AOPCs may be contaminated. The "footprints" are based on the data that characterize the upper basalt units (the Priest Rapids and Roza 1 aquifers). Persons drawing water from the alluvial Hanford aquifer are not expected to be consuming water above the PRAG.

The AOPCs are depicted on figure 2.2-1, which also includes the land use categories that overlay the plumes: airport and commercial, UGA, and rural residential zoning. For current exposures, there are individual residential wells and small systems (< 5 families on a single property) in both rural residential and UGA that may draw contaminated water ($> 5 \mu\text{g/L}$ TCE) from one of the plumes. For future exposures, it is assumed that the infrastructure will be extended to permit all of the residences in the UGA to connect to CML water or another local water purveyor, if

they desire. (In chapters 3 and 4, land-use control measures are described to reinforce zoning conditions in order to assure reduction of public exposure.) However, as noted further in chapter 3, those rural residences outside the UGA cannot be assumed to be part of a future CML water system extension and there are no other water purveyors in the area. RAOs also apply through a more extensive monitoring network outside of the AOPCs, to assure that the AOPCs are appropriately characterized and the concentrations are not showing an upward trend. (The monitoring network is described in subsequent chapters.)

In section 2.1, it was stated that, for RAO 2, the reduced plume (or plumes) should be entirely limited to areas within which existing controls are more likely to be protective of human health, e.g., areas where no residential habitation occurs such as areas zoned commercial industrial or Port owned. As currently drawn (figure 2.2-1), the southern boundary of AOPC 2 barely extends into residential zoned property and may nearly meet this criterion, although it must be noted that there is uncertainty about the southern extent of AOPC 2 (see section 1.5.4). However, for the AOPC 2 northeastern flank, residential properties exist that are outside of the UGA in the area currently zoned rural-residential. Therefore, for this portion of the AOPC, attainment of RAO 2 would require the reduction of plume to within the treatment/capture zone of the treatment or extraction well.

For AOPC 1, in contrast to AOPC 2's southern extent, much of the plume is in an area that is residential (the purple area in figure 2.2-1). RAO 2 could be met by drawing the plume back to the commercial-industrial land-use category.

As described above, acetone is a narrow-scope COC, found only at well 02-BW02. At a minimum, follow-up testing at the well for acetone will be needed.

2.2.4.2 *Limitations Relating to Lack of Discovery of Source*

USEPA (1995c) states the following:

"The goal of ground-water cleanup at Superfund sites continues to be restoration of contaminated ground water to ARAR based cleanup levels wherever technically practicable. However, evaluations of 'pump and treat' remedies published by EPA in 1989 and 1992 indicated that complete restoration of many ground-water contamination sites in the Superfund program might not be technically practicable with available remediation technologies due to the presence of nonrecoverable DNAPLs, or for other reasons related to complex site hydrogeology or contaminant characteristics. Where such factors constrain ground-water restoration, the Superfund program's approach is to emphasize removal or treatment of source materials; containment of nonrestorable source areas; and restoration of aqueous contaminant plumes.

"The National Research Council's recently released report 'Alternatives for Ground Water Cleanup' independently confirmed EPA's findings that available ground-water remediation technologies are limited in their ability to restore all portions of contaminated ground-water sites. However, the NRC report also pointed out that, despite these constraints: 1) Nonrestorable areas at complex sites

generally constitute relatively small portions of the overall ground-water contamination problem; and 2) Pump and treat and other technologies are capable of restoring large portions of such sites, and of providing significant environmental benefits. The NRC report is therefore consistent with the current Superfund approach to ground-water remediation.”

The discussion of the state of knowledge of the Site’s TCE source areas (sections 1.5.3 and 1.5.4) indicated that there are data gaps regarding their location, both vertical and horizontal. USEPA (1993d) issued *Guidance for Evaluating Technical Impracticability of Ground-Water Restoration* to inform decisionmakers when conditions are not suitable for complete aquifer restoration. The guidance states that site related factors, which may reduce ability to accomplish this goal, may be considered. The factors with the highest likelihood of making a site cleanup impracticable (highest rank in parentheses) include: (1) Duration of release (longer); (2) attenuation or breakdown (low); (3) degree of sorption of the chemical to the substrate (high); (4) stratigraphy (high complexity of geology, high heterogeneity); and (5) flow velocity (slow). Virtually every one of these factors exists at this Site or there is substantial uncertainty regarding quantifying the factor. This Site is unusually challenging to restore aquifers completely to beneficial use because of the complex stratigraphy with fractured basalt aquifers. A substantial effort to locate source areas has been unsuccessful. It is therefore possible that the PRAG will not be met throughout all aquifers at all areas of the Site. It is more likely that the extent of TCE contamination in aquifers may be reduced to areas where the public exposure is readily controlled, thus achieving the benefit of protectiveness.

There may be instances when USEPA determines that it is impracticable to attain complete aquifer restoration. A “Technical Infeasibility Waiver” may be initiated by USEPA or other administrative alternatives may be implemented, such as provisional compliance zones (40 CFR 300.430(f)(1)(ii)(C)).

2.3 GENERAL RESPONSE ACTIONS

The first step toward defining remedial technologies and associated process options is to develop GRAs. GRAs are site-specific and medium-specific categories of actions that will satisfy the RAOs. The GRAs identified for groundwater at this Site are:

- No Action.
- ICs.
- Other Controls.
- Containment.
- Ex-Situ Treatment.
- In-Situ Treatment.

The subsequent portions of this section further define the GRAs for the Site. The media of concern to be addressed by these GRAs are subsurface soils (at depths greater than 15 ft bgs) and groundwater within AOPCs 1 and 2 in the Priest Rapids-Roza 1 and Roza 2 aquifers.

Soils shallower than 15 ft bgs are addressed in the SSFS, although for specific PSAs (Site 19, for example) the SSFS addresses deeper soils, as well.

Following development of the GRAs, screening and evaluation of remedial technologies and associated process options are undertaken. The term "remedial technologies" refers to, for example, physical treatment and thermal treatment and are remedial technologies within the in-situ treatment GRA. Process options may exist for certain types of technology. For instance, steam and electrical resistance heating are process options within the thermal treatment remedial technology. Sections 2.5 and 2.6 accomplish the identification, screening, and evaluation of technologies and process options. Possible presumptive remedies for the GRAs are discussed in section 2.4.

2.3.1 No Action

Pursuant to 40 CFR 300.403(e)(6) of the revised NCP (March 8, 1990) and the USEPA's guidance for conducting a RI/FS (USEPA, 1988), a "no-action" option must be developed and examined as a potential remedial action for all sites. Therefore, this action is retained for further consideration as a baseline comparison with other remedial actions.

2.3.2 Institutional Controls

ICs, such as land-use restrictions and water-use restrictions, can be used to prevent or reduce exposure to soil and groundwater contaminants. ICs are typically divided into governmental and proprietary controls:

- Governmental controls are usually implemented and enforced by State or local Government and can include zoning restrictions, ordinances, statutes, building permits, or other provisions that restrict land or resource use at a site. Governmental controls remain effective so long as they are not repealed and are enforced.
- Proprietary controls, such as easements and covenants, include private land use restrictions that typically result by agreement with the landowner and an enforcing party that may be a neighboring landowner, a State environmental agency, or a local civic association. These controls are sometimes termed "deed restrictions," because the restriction typically becomes placed within the chain-of-title to the restricted property. These types of controls can be binding on subsequent purchasers of the property (successors in title), and are transferable. This may make them more reliable than other types of ICs in the long term. However, proprietary controls are dependent upon real property common law and may be complex with respect to owners' rights and the ability of an owner to convey certain rights (such as a long-term access for groundwater monitoring) to other entities while keeping other rights to the property (USEPA, 2000).

Additional measures, including enforcement tools (such as administrative orders and consent decrees) and informational devices (such as deed notices, State registries of hazardous waste sites, educational programs, and issued advisories), are also considered ICs.

2.3.3 Other Controls

Other controls typically include alternate water supplies, individual well treatment, physical barriers, and groundwater monitoring. Physical barriers, alternate water supplies, and individual well treatments are methods used to prevent exposure to contaminated media. Groundwater monitoring may be used to evaluate contaminant migration, monitor natural attenuation, and evaluate remedial system performance. For this Site, natural attenuation is considered an additional control due to its likely minor role in contaminant reduction at the Site. This is based on the lack of widespread TCE degradation products and other groundwater data indicating that site conditions are not favorable for breakdown of TCE by removing chlorine atoms (reductive dechlorination).

2.3.4 Containment

Containment involves the installation of vertical barriers, groundwater extraction and collection systems, or capping to control, arrest, or divert groundwater plume(s) and groundwater contamination source(s). The type of containment method used depends upon site-specific parameters such as soil type, depth to bedrock, type of contamination, contamination concentration, depth of contamination, identification of a source, size of contaminant plume, and aquifer permeability (Burns and McDonnell, 2004).

The objective of containment as a response action is to control the migration of chemicals in groundwater. When assembled into alternatives, all of the containment options will need to include groundwater monitoring and ICs as previously described. In addition, the containment options would require some degree of groundwater extraction to maintain an inward gradient into the containment area. Available technologies for groundwater extraction will be combined with treatment and disposal options discussed in the following sections.

2.3.5 Ex-Situ Treatment

Ex-situ treatment refers to the actions a contaminated medium undergoes after being extracted from its natural setting. This treatment can be applied to soil via excavation, groundwater via pumping, and soil vapor via soil vapor extraction. Once a contaminated medium is extracted, it can either be disposed of without treatment (so long as it meets appropriate criteria for doing so), or the medium can undergo ex-situ treatment. Ex-situ treatment can be employed either onsite or offsite, depending on the remedial design.

2.3.6 In-Situ Treatment

In-situ treatments are remedial technologies that are applied to the media of concern in their natural setting. Typically, in-situ treatments result in reduced treatment costs and environmental impacts, particularly with land treatments. In-situ treatments may have complex designs and be more difficult to implement and manage than ex-situ treatments. In-situ treatments are preferred in situations where the contaminant source is dispersed over a large volume; where the source is beyond the reach of conventional excavation/extraction at a reasonable cost; and when excavation/extraction is not possible on safety, engineering or environmental grounds, or where infrastructure prevents excavation/extraction. In-situ treatments may be designed to meet RAOs

for small or large contaminated media volumes, low to high contaminant concentrations, and for most geological conditions (Bardos, 2000).

2.4 PRESUMPTIVE REMEDIES

Presumptive remedies are designed to simplify and streamline the technology screening process in a FS for a CERCLA site. USEPA guidance on presumptive remedies and treatments came out of the Superfund program's experience to meet a need for more consistent remedies and remedy implementation across similar types of sites, thereby reducing costs and time to cleanup sites grouped by site characteristics (USEPA, 1996a). The presumptive remedy list is based on the historical patterns of remedy selection and evaluations of remedial systems for various types of sites. The USEPA guidance is intended to be used at all appropriate sites as defined in the USEPA directive, *Presumptive Remedies: Policy and Procedure* (USEPA, 1993a).

Existing presumptive remedy guidance documents cover:

- Volatile Organic Compounds (VOCs) in soil – site characterization and technology selection (USEPA, 1993b).
- VOCs in soil – general presumptive remedies (USEPA, 1996b).
- Landfill soil covers (USEPA, 1995a).
- Municipal land fills (USEPA, 1993c).
- Soils, sediments, and sludges at wood treater sites (USEPA, 1995b).

The presumptive remedies for VOCs in soil would be applicable to the Site if a subsurface soil TCE source is discovered. However, to date, no subsurface soil TCE source has been discovered. (As noted, PSA 20 has the potential to be a vadose source, but this information is uncertain.) No presumptive remedy guidance exists for any specific type of groundwater contamination. However, USEPA has created a presumptive response strategy as an extension of the presumptive remedy approach, USEPA (1996a) *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Groundwater at CERCLA Sites*. The goal of this guidance is to present a streamlined process to select a remedy appropriate for any study site in lieu of presenting a single technology for a specific category of sites. This presumptive response approach allows for greater complexities within a site and variations between sites than a presumptive remedy does. This remedy process can be followed to a remedy selection regardless of the exact site characteristics. The presumptive response strategy focuses on cost savings and reducing the length of time to meet RAOs over the long term with the remedy.

2.5 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

The purpose of this section is to identify and evaluate potential remedial technologies for groundwater at the Site. Based upon conclusions from section 2.2.4, action is warranted on the two AOPCs to protect against exposure and to address groundwater where TCE exceeds the MCL. The selection of potentially feasible technologies is comprised of two steps:

- Identification and initial screening of potential remedial technologies and process options.
- Evaluation of remedial technologies and process options.

The initial step taken in the technology evaluation process consists of the identification of potentially applicable technologies and process options that may be used for the management, containment, treatment, and/or disposal of contaminated soil and groundwater. Technologies selected for preliminary screening represent a wide range of responses commonly used to address soil and groundwater contamination. Both fully developed and emerging processes are considered in this regard. Technologies and process options for this Site are presented in table 2.5-1.

Identified technologies are initially screened to eliminate technologies that cannot be effectively implemented. Process options are to be removed from further consideration if they are not technically feasible at the Site based on site-specific conditions such as aquifer characteristics, the volume of impacted groundwater, and the chemical characteristics of compounds of interest. Tables 2.5-2 and 2.5-3 show the screening of considered technologies and associated process options for each medium of concern (subsurface soil and groundwater). Process options that are considered implementable at this Site are retained for a comparative evaluation within the technology. The process options comparative evaluation is carried out in section 2.6 and detailed in table 2.6-1.

The following section describes the process options considered and screened out from the comparative evaluation of process options and, therefore, are eliminated from further consideration in this FS for use at the Site.

2.5.1 Technologies and Process Option Screened Out for Subsurface Soil

All groundwater-related remedial technologies and process options for subsurface soils were screened out due to lack of an identified source to which a remedial technology would be applied. Despite attempts to identify vadose and saturated zone sources for TCE, none has been located. Until one is found, no action may be defined or subsurface soil. A possible exception is PSA 20, for which a shallow surface soil removal or an impermeable cap to reduce infiltration may be warranted. (See the SSFS for further discussion.) For a newly discovered TCE source in future, actions could be identified per the presumptive guidance (USEPA 1993b and 1996b, and section 2.4). Because no process options or technologies are retained for evaluation, the only remaining GRA still applicable to the subsurface soils is the "No Action" GRA.

2.5.2 Technologies and Process Options Screened Out for Priest Rapids-Roza 1 and Roza 2

The following discussions summarize table 2.5-3. The following technologies and process options have been screened out due to not being effectively implementable in either aquifer (Priest Rapids-Roza 1 and Roza 2) at the Site.

2.5.2.1 Containment

Soil mixing walls, sheet pile walls, and slurry walls are eliminated from further consideration for use at the Site, because they are not generally practical deeper than 100 ft bgs. If pumping for extraction and groundwater treatment were to be implemented at the Site, no additional benefits would be gained by installing a barrier wall. Extraction is a portion of other alternatives. Therefore, barrier walls are eliminated.

Oil filling of bedrock fissures is eliminated. The AOPCs are too large and the location of the sources too uncertain to effectively implement this process option.

Drawdown pumping and re-injection downgradient of the source is best used for source reduction and is, for the same reasons as shown above, not believed to be suitable.

2.5.2.2 Ex-Situ Treatment

Separation is used to separate various types of COCs into separate, treatable components. There is no need for such a treatment at the Site, because TCE is the only wide-area COC.

Distributing the extracted groundwater for sprinkler irrigation as an ex-situ treatment is not considered likely to be effective based on difficulty for selecting distribution routes and the inability to treat year round.

Constructed wetlands were screened out due to difficulty in creating and maintaining a wetland on the extremely pervious alluvial soils at the Site.

2.5.2.3 In-Situ Treatment

Air sparging is not retained for use at the Site due to the existence of confining layers (layers that would not allow for the migration of vapors from the subsurface) between the Priest Rapids/Roza 1 and the Roza 2 aquifers and the unconsolidated alluvial soil.

Bioslurping is eliminated based on this process option, because it is best suited for source treatment and not effective on low-level TCE concentrations currently observed in Site groundwater.

Dual-phase extraction is a source treatment and is not suitable for low-level dissolved-phase TCE plumes in the absence of an identified NAPL source.

Biodegradation under anaerobic conditions is eliminated based on the strongly aerobic conditions of site groundwater (for both Priest Rapids-Roza 1 and Roza 2). While it is possible to introduce enough carbon to create an anaerobic aquifer, this condition could affect downgradient water quality and taste.

Phytoremediation is not retained for use at the Site due to the depth to groundwater.

Steam injection and electrical resistant heating are eliminated from consideration for both aquifers because thermal treatment is best suited for source treatment and cannot be effectively implemented on low-level concentrations, such as the ones at this site.

2.5.2.4 Treatment Technology Components

Direct-push injection is eliminated for consideration based on past experience at the Site where direct-push techniques were unable to penetrate the unconsolidated overburden to depths required to reach the Priest Rapids-Roza 1 aquifer. If a direct-push technology can be proven to meet the depth needs at the Site, then this technology may be reconsidered.

Hydrofracturing is eliminated, because it is ineffective at accelerating treatment of dissolved-phase plumes in permeable media, such as the ones at this site. This technology, too, may be reconsidered should the current CSM change with additional information obtained during the remedial design phase.

2.5.3 Technologies and Process Options Screened Out for Roza 2 only

Although retained for the Priest Rapids-Roza 1 aquifer, passive/reactive treatment walls are screened out, because they are not implementable in the deep Roza 2 aquifer.

2.6 EVALUATION OF RETAINED PROCESS OPTIONS

Following the initial technology screening, potentially applicable process options are compared to determine which process option is the most effective, implementable, and cost-effective for a technology. The goal of the evaluation is to select the best process option(s) to bring forward into the assembly of remedial alternatives. Section 2.6 describes the evaluation procedures, criteria, and outcomes. For each medium of concern (subsurface soil, Priest Rapids-Roza 1 aquifer, and Roza 2 aquifer) only the most effective, implementable, and cost-effective process options are retained. For the treatment GRAs, the goal is to have one process option selected for each type of treatment (ex-situ and in-situ); for the other action GRAs, an alternative having multiple process options and technologies is acceptable.

Following USEPA guidelines (USEPA, 1988), the evaluation method considers the relative effectiveness, implementability, and cost of each process option within a technology for achieving the RAOs. In general, specific technology processes are evaluated based on these three criteria relative to other processes within the same technology type.

The effectiveness of the process option focuses on (1) the applicability of the process option for the given site characteristics (such as geology and hydrogeology), treating the estimated area and/or volumes of a contaminated medium, and the ability of the process option to meet the identified RAOs; (2) the potential impacts to human health and the environment during implementation of the process option; (3) how proven and reliable the process option is known to be; and (4) the relative cleanup time to meet RAOs.

Implementability considers the technical and administrative feasibility of using the technology after consideration of conditions at the Site. Technical considerations include additional

treatments, residuals produced, the ability to construct, maintain, and operate the technology, and the ability to comply with regulations. Administrative considerations include the ability to obtain necessary approvals and the availability of equipment, materials, and services.

The relative cost evaluation of each process option focuses on a qualitative evaluation of the capital and operation and maintenance (O&M) costs to implement the technology as compared to other options in the same technology group and the overall cost of the process option compared to other groundwater remediation techniques. These costs may vary significantly from site to site and are used only as a preliminary indication of financial resources required to implement each technology. At this stage of the FS process, effectiveness and technical implementability evaluations of process options are more important than administrative implementability and cost analyses.

The initial screening of technologies and general comments regarding potential benefits or limitations for each considered process option for each medium of concern are provided in tables 2.5-2 and 2.5-3. From the technology screening, several process options are identified as potentially feasible options for groundwater remediation at the Site. "No Action" was selected for subsurface soils. Table 2.6-1 shows the comparative evaluation of technologies and process options retained after the screening for development of potential remedial alternatives and provides the rationale for eliminating process options from further consideration.

Not every listed process option and technology receives the same level of scrutiny with respect to the evaluation criteria. For example, governmental ICs pass the evaluation without a strict breakout of plusses and minuses. Additionally, certain remedial technologies have only one associated process option in table 2.6-1. These process options are rated by comparing other process options within the GRA, but are automatically carried through for the assembly of alternatives. Most process options in the "Other Controls" GRA are not evaluated against the three criteria in the same strict manner that the Containment, Ex-Situ Treatment, and In-Situ Treatment process options are, but are nonetheless generally evaluated. The generalization is acceptable in these cases due to the requirement that the action at least be part of a limited action alternative. The Containment, Ex-Situ Treatment, and In-Situ Treatment process options are compared in more detail and more closely follow the guidance criteria.

2.6.1 Institutional Controls

Within the GRA of ICs, no IC options are eliminated during the screening.

2.6.2 Other Controls

Other control technologies for this site have been selected to include alternate residential water supply, individual well treatments, long-term monitoring, and natural attenuation monitoring. Process options retained include connections to either CML water or another local water purveyor, installation of a new well, and activated-carbon point-of-use filters. Provided (bottled) water was eliminated from the alternate water supply, because it is not a long-term solution and has high relative cost. Low-profile air stripping and UV filtration point-of-use systems are also eliminated.

2.6.3 Containment

Section 2.5 indicated that this technology was not feasible for Priest Rapids-Roza 1. Deep soil mixing walls, sheet pile walls, and slurry walls are all eliminated for logistical reasons.

2.6.4 Ex-Situ Treatments

For the level of evaluation to this point, it was not possible to determine whether adsorption/absorption (granular activated charcoal [GAC]) or air stripping would be more effective, implementable, or cost effective for the Site. These two process options had equivalent ratings for each category and both will be carried forward as a generic physical/chemical technology until a selection of one process option over the other can be made. The other evaluated physical/chemical process options (advanced UV oxidation and deep well injection) and the biological treatment (bioreactors) technology are eliminated based on their comparison to activated carbon and air stripping.

2.6.5 In-Situ Treatments

For in-situ treatments, in-situ chemical oxidation, e.g., sodium permanganate (NaMnO_4), and in-situ reduction are selected as the best process options for the Site. As with ex-situ treatments, the FS-level scope for evaluation does not permit a decision between the two processes. However, nanoscale zero-valent iron (ZVI) is retained as the generic in-situ treatment method for costing purposes in the GWFS. Whether NaMnO_4 , nanoscale ZVI, or another reagent is used may be postponed until the remedial design phase in order to allow for the selection of the best process option for site conditions. The other evaluated physical/chemical process options (in-well stripping, funnel and gate passive/reactive treatment wall) and the biological treatment (biodegradation under aerobic conditions) technology are eliminated based on less anticipated effectiveness than nanoscale ZVI or NaMnO_4 .

2.6.6 Treatment Technology Components

The retained fluid delivery systems (either extraction or injection) and system enhancements are vertical, horizontal, and circulating wells. Air emission treatment process options may not be needed depending on the remedial design. For vapor treatment, activated carbon and oxidation had the best results of the four options. High-energy destruction and membrane separation are eliminated. Specific vapor treatment options will be selected during remedial design.

CHAPTER 3

Development & Identification of Remedial Alternatives for Detailed Analysis

CHAPTER 3. DEVELOPMENT AND IDENTIFICATION OF REMEDIAL ALTERNATIVES FOR DETAILED ANALYSIS

3.0 INTRODUCTION TO ALTERNATIVES DEVELOPMENT PROCESS

In this chapter, technologies and processes that survived the screening process in chapter 2 are organized into “assemblies,” and then into alternatives. Assemblies are combinations of technologies/processes that are discussed in context of Site needs. Alternatives are, in effect, groups of assemblies that are attuned to AOPC- and aquifer-specific remedial needs. In chapter 3, the alternatives are evaluated against three criteria (effectiveness, implementability, and cost) to assure that they are viable. Viable alternatives, following USEPA (1989) guidance for RI/FS, will be subjected to more detailed analysis against seven of nine CERCLA criteria in chapter 4⁵.

Effectiveness is the ability of an alternative to meet RAOs defined in chapter 2, the ability of an alternative to reduce toxicity, mobility, or volume of contaminants, and the short- and long-term aspects. Effectiveness considers long-term effectiveness and permanence in eliminating exposure pathways or reducing levels of exposure above the PRAGs. Short-term effectiveness considers exposures related with implementation of alternatives and for that period during which PRAGs are still not met.

The RAOs from chapter 2 are:

- RAO 1. Prevent human exposure to contaminated groundwater.
- RAO 2. Minimize horizontal and vertical extents of groundwater contaminant plumes exceeding PRAGs.
- RAO 3. Prevent or minimize further migration of contaminants from source materials to groundwater.

Individual assemblies generally target attainment of one or more of the RAOs. Thus, several assemblies may be necessary for an alternative to achieve all of the RAOs. RAO 1 is a goal for short-term effectiveness. RAO 2 is an intermediate goal in both preventing exposure and restoring the aquifer. RAO 3 is a goal relating to long-term effectiveness. As described above, there is uncertainty regarding meeting ARARs as described via RAO 3, because there are no

⁵ The seven CERCLA criteria are (1) overall protection of human health and the environment, (2) compliance with relevant state and Federal law, (3) long-term effectiveness and permanence, (4) reduction of toxicity, mobility, or volume of contaminants through treatment, (5) short-term effectiveness, (6) implementability, and (7) cost. Two further CERCLA criteria are fulfilled by the publication of the Proposed Plan and public and stakeholder review. They consist of (8) State acceptance, and (9) community acceptance.

clearly delineated groundwater-based or vadose soils-based source areas. As described above, there is doubt whether more information would lead to their delineation.

Implementability addresses whether an assembly or alternative is technically and/or administratively feasible, and whether required goods and services are available. Examples of the former include: (1) Expert opinions on application of a technology in deep, fractured basalt; (2) ability and willingness of local jurisdictions to enforce ICs; and (3) ability to monitor long-term effectiveness. Examples of the latter include: (1) Ability to construct, operate, and maintain the remedy and (2) ability to phase in contingent actions, if needed.

Order-of-magnitude costs include capital and operating costs for the remedial action, long-term monitoring costs, and maintenance. Relative costs are approximate, and in chapter 4, they will be further refined and compared across alternatives. In chapter 3 screening, the intent is to determine whether an alternative might not be viable due to exceedingly high costs associated with site conditions. Chapter 4 costs are for detailed inter-alternative comparisons.

3.1 ASSEMBLY DESCRIPTIONS

Assemblies are intended to target RAOs, as shown in table 3.1-1.

3.1.1 Assembly 1 — Basic Action

Assembly 1 is considered for application in both AOPC 1 and AOPC 2, and for the Priest Rapids-Roza 1 and Roza 2 aquifers. (Subsequent alternatives development will distinguish between these four application areas/depths.)

The “Basic Action” assembly includes multiple layered actions that are intended to address RAO 1 (prevent exposure to contaminated groundwater). The Basic Action assembly will not meet RAO 2 (minimize horizontal and vertical extents of groundwater contaminant plumes exceeding PRAGs) or 3 (prevent or minimize further migration of contaminants from source materials to groundwater). This assembly will be required no matter which alternative is selected. The exact combination of possible actions within the Basic Action category will depend on the ability of other assemblies to meet RAOs. The Basic Action assembly includes a toolbox of the following: (1) ICs, (2) alternate water supply, (3) individual well treatments and a domestic well sampling program, and (4) long-term monitoring, including compliance monitoring for COCs and natural attenuation parameters.

3.1.1.1 Basic Assembly Option 1a — ICs

As noted in chapter 2, ICs comprise nonengineering measures designed to prevent or limit exposure to hazardous substances left in place (in this case, TCE remaining in groundwater for an unknown period), or to assure effectiveness of the chosen remedy. ICs are anticipated to be required at the Site within the areal extents of both AOPC 1 and 2 to ensure meeting RAO 1. ICs may include legal controls such as easements, restrictive covenants, and zoning ordinances, as well as other actions such as groundwater use restrictions described in table 2.5-1. However, at this Site, it is likely that ICs for the Site may comprise mandatory water testing for Group A and B water supplies, plus education programs or publications to inform individuals whose new or

existing well may be within a contaminated zone, and to encourage voluntary testing; the follow-up would be alternate water supplies (see next paragraph). All of these controls are intended to be layered for long-term prevention of exposure; individual length of effectiveness and implementability will vary with the IC. Table 3.1-2 describes actions for monitoring and authorities.⁶

3.1.1.2 Basic Assembly Option 1b — Alternate Water Supplies

In order to meet RAO 1 for the long term, alternate drinking water supplies must be available for those systems and individuals with water exceeding the PRAGs identified in chapter 2, chiefly for TCE the PRAG of 5 µg/L. Three categories of alternate water supplies are retained as components for this assembly. The categories were:

- Public water supply provided by the CML.
- Public water supply provided by a noncity Group A or Group B water purveyor.
- Installation of a replacement well screened in an uncontaminated aquifer.

The type of alternate water supply selected will be developed on a case-by-case basis, so that the best option can be selected for a given situation. An additional condition influencing the selection of an option is whether the well in question is within the CML UGA boundary, as shown in figure 2.2-1. If within the UGA, then water from the CML is assumed as a future likelihood. However, if a contaminated well is outside of the UGA, CML water hookup is assumed in this GWFS to be unavailable in the future. (There are no water purveyors in the portion of AOPC 2 that lies outside of the UGA.) Costs for extending water supply lines and sewage connections are considered as part of the remedy for nonservice areas; costs to individual landowners for purchasing water and other improvement costs are not factored in.

Table 3.1-2 identifies possible water supply actions that would provide an alternate source of water. The table distinguishes between Group A and Group B water supply systems, existing individual residential wells, and existing and new wells associated with construction. These distinctions are necessary because different categories have different regulatory requirements and remedial needs. For instance, Group A and Group B wells are regulated by Washington Department of Health and the Grant County Public Health District, and testing is required; therefore, contamination in these systems could be known. Construction of all new wells requires an Ecology design review; and that contact with Ecology could be used to inform the prospective well builder that contamination exists. However, existing individual residences and construction or commercial wells that do not require a new construction permit are unregulated and contamination could be present in that location but remain undiscovered. For these wells, because there is no existing enforcement program, an information program to encourage sampling is a possible element.

Figures 1.3-1 and 1.3-2 show the UGA and water purveyor systems. Figure 2.2-1 shows the AOPCs overlaid upon the land use classification. From these figures, no independent Group A or B water purveyors are collocated with the northeast subarea of AOPC 2 outside of the UGA.

⁶ It is assumed that listed authorities are willing to enforce the institutional controls listed for their jurisdictions.

In that subarea, short-term provision of drinking water or point-of-use filter and consideration of providing long-term alternative water supplies will need to be considered. For other user categories, long-term actions would include either connection to CML water or connection to another local water purveyor.

3.1.1.3 Basic Assembly Option 1c – Point-of-Use or Wellhead Water Treatment

Installation and maintenance of point-of-use filters or wellhead treatments are engineering controls and are therefore inappropriate as long-term solutions for ensuring that RAO 1 is met; for these, an alternate water supply (see above) is required as a long-term solution. The point-of-use filters are typically GAC filters. Point-of-use filter installation, maintenance, and water sampling would continue until one of the long-term alternate water supplies could be implemented. If a short-term treatment is required for a Group A or Group B water purveyor, then either an activated carbon filter or an air-stripping system may be applied based on relative cost for the specific system. These short-term prevention measures for individual well owners are based upon voluntary testing and agreed-to filter installation and O&M.

3.1.1.4 Assembly 1d – Long-Term Monitoring

Monitoring wells are a standard technique used to establish presence of contaminants in groundwater (through collection and laboratory analysis of samples) and monitor effectiveness and protectiveness of remedies. All of the “action” alternatives will have some type of long-term monitoring associated with them. However, monitoring alone would not meet any of the RAOs. There are three categories of monitoring wells for the Site. Existing and new monitoring wells, and possibly sampling from domestic wells, may be used to track contaminant concentration trends. Wells would be selected or installed at a distance from treatment areas (at which wells are considered system performance wells) and from compliance zones (at which wells are considered compliance wells). As the remedy progresses and the plumes diminish in size, it is possible that compliance wells could become long-term monitoring wells. COC concentrations and natural attenuation parameters may be measured during long-term monitoring.

The existing monitoring network will likely be insufficient to address all of the RAOs. New monitoring wells may be placed in the alluvial, Priest Rapids-Roza 1, Roza 1, Roza 2, or Roza 3 aquifers. For cost comparison in this chapter, a general estimate is used to represent the range of possible long term, compliance, and performance-monitoring wells that may be required based on the remedy selected and its remedial design. For costing purposes, 80 new monitoring wells, divided between the Priest Rapids-Roza 1 and Roza 2 aquifers, and 50 existing monitoring wells, with a mix of quarterly and yearly sampling for the first 5 years of action, are used as the cost basis. The exact location and depth of the new wells is not specified in either FS, but is left to the remedial design phase.

3.1.1.5 Basic Assembly Option 1e – Surface Barriers (Fences)

Fencing is an incidental assembly that will likely be used to protect wellheads of contaminated wells from use as a drinking water source. Fencing may also be used to provide secure storage for investigation-derived wastes from monitoring.

3.1.2 Assembly 2 – Groundwater Extraction for Hydraulic Containment

Hydraulic containment relies on groundwater pumping to restrict migration of the contaminant plume or source. Depending upon the layout of the well network, extracted water may or may not be treated to remove TCE before it is re-infiltrated or re-injected. Typically, extraction wells provide containment by establishing overlapping zones of hydraulic influence (capture zones) to create hydraulic containment.

Groundwater extraction solely for hydraulic containment may accomplish RAOs 2 (minimize horizontal and vertical extents of groundwater contaminant plumes exceeding PRAGs). Two scenarios for hydraulic containment could be used at the Site. One scenario would create a bypass of the “hotspot” zone. Clean water upgradient of a suspected source is extracted and re-injected downgradient of the suspected source. This action would tend to confine the contaminated groundwater to the area nearest the source, but would not result in treatment, per se. Over time, it is possible that TCE concentrations would rise in the source vicinity due to a longer contact time with the source, and “leakage” from the confinement could occur. Hydraulic containment would not be viable as a stand-alone action. Thus, it would have to be used in conjunction with a groundwater treatment.

3.1.3 Assembly 3 –Groundwater Extraction with Ex-situ Treatment Assembly

To remove TCE from extracted groundwater, two technologies are typically used in conjunction with extraction, sorbents (e.g., GAC), and air stripping. Groundwater extraction options are discussed first and are followed by discussion of ex-situ treatment components of the assembly.

3.1.3.1 Groundwater Extraction Well Array Design

The following paragraphs detail the rationale for the placement of extraction wells within an AOPC in order to optimize treatment of the contaminant plume. Various extraction well arrays are conceptually evaluated below. These arrays may be applied to either AOPC and to either the Priest Rapids-Roza 1 or the Roza 2 aquifers. Given the difficulty in clearly defining a source or source area in bedrock, it is assumed that groundwater extraction will be managed with the intent of cutting off the suspected source and starving the downgradient dissolved-phase plume. Because sources have not been identified during site investigations, the most effective extraction scenarios target contaminant “hotspots” that are believed to reflect proximity to the sources.

Figure 3.1-1 depicts four conceptual groundwater extraction design options for the groundwater extraction. Injection wells (not shown) may be added to enhance flushing through the aquifer and, thereby, reduce cleanup times. Effects on contaminant plume distribution are illustrated for three time periods: initial (year 0), intermediate (year X), and long term (year multiple X). Design option “A” indicates a plume-wide groundwater extraction array with wells in a dispersed pattern within the plume. Design option “B” shows a leading edge placement of extraction wells only along the downgradient front. Design option “C” shows wells clustered as a line in the immediate vicinity of, and downgradient of, the known hotspot (and thus, the suspected source area), and is called a hotspot cut-off extraction array. Design option “D,” a modified hotspot cut-off, is a combination of designs A and C. Please note that the figure

is diagrammatic. Further aquifer characterization and numerical modeling would be essential during remedial design to enumerate and refine well placements.

Both options that concentrate wells at the leading edge (options A and B) are less efficient and effective. Because current information indicates that the plumes are stable (i.e., contamination does not seem to be migrating downgradient), treatment near the leading edge would be extracting lower concentrations of TCE (approximately 5 to 15 µg/L) than nearer the likely source areas (approximately 40 to 80 µg/L TCE). Therefore, leading edge pumping would not as effectively reduce the area of contamination as would dispersed or source cut-off extraction arrays. In addition, the larger pumping volumes and greater number of wells to control the broader leading edge could have adverse effects on access to downgradient groundwater users by reducing the quantity of water flowing through the basalt aquifers and/or having greater cost. The effect of intercepting and removing groundwater can be mitigated by re-injection of treated water downgradient of the extraction wells, thereby maintaining water balance in the aquifer.

Options that have hotspot cut-off (C and D) are more effective in the short and long terms in reducing the extent of contamination than options A and B. By pumping nearer the source, the downgradient plume is starved for TCE. In option C, the leading edge might persist for a longer time than in the modified hotspot cut-off (D) array, which appears to be the most effective in reducing the areal extent of >5 µg/L TCE in shorter timeframes. The tradeoff is that option D is less efficient overall due to extraction of marginally contaminated groundwater at the leading edge of the plume. Option C is selected for the assembly, but D may be considered if the times to achieve RAOs are excessively long.

A weakness common to ex-situ assemblies and in-situ treatment assemblies is possible "rebound" or return in the groundwater to pre-treatment concentrations once active remediation ceases for as long as NAPL sources remain. Therefore, these assemblies are expected to extend for long remediation periods. For groundwater extraction and ex-situ treatment, the timeframe for remediation is assumed to be 30 years for costing purposes. Additional pumping in the downgradient plume area can be considered here as a contingent action if the downgradient cleanup is taking place at a rate much slower than anticipated in this study.

3.1.3.2 Assembly 3a – GAC Sorption from Groundwater

Extracted groundwater would be passed through a packed or fluidized column. As noted in chapter 2, the most common adsorbent for this purpose is GAC. The sorption capacity of GAC is longer for low concentrations in the range seen at the Site. Upon sorption of TCE to the design capacity, the GAC is typically regenerated offsite using heat at a commercial facility. The off-gassed TCE is typically incinerated at the industrial regeneration site. The spent media may be disposed of in a landfill.

3.1.3.3 Assembly 3b – Air Stripping of Groundwater

Air stripping involves the mass transfer of volatile contaminants from water to air. Air stripping is well suited for volatile chemicals, such as TCE, and for concentrations at or above the range observed at the Site. For groundwater remediation, this process is typically conducted in a packed tower or in a tray tower. The typical packed tower air stripper includes a water

distributor at the top of the tower to distribute contaminated water over the packing in the column, a fan to force air countercurrent to the water flow, a sump at the bottom of the tower to collect decontaminated water. Vapor treatment may be required, as well, if effluent COC concentrations exceed ARARs. Given the relatively low dissolved-phase concentrations of TCE present at the Site, it is unlikely that treatment of vapor effluent would be necessary. Air strippers can be installed as permanent installations on concrete pads or for temporary use on a skid or a trailer. Due to its common use and suitability to the type and concentrations of contamination, air stripping is also retained as a possible ex-situ treatment.

3.1.4 Assembly 4 – In-situ Treatment of Groundwater by Injection of Reagents

Assembly 4 involves injection of a reagent into the affected aquifer as a means to promote an in-situ chemical oxidation or an in-situ reduction of TCE. This assembly requires injection wells to deliver the reagents to the desired treatment zone and selection of a reagent suited for site conditions. To the extent that this assembly can target a subsurface source, in-situ treatment may meet RAO 3 (prevent or minimize further migration of contaminants from source materials to groundwater) better than other assemblies. Also, uncertainty in the precise location of NAPL source zones at the Site means that injection wells will need to be installed over a larger area than occurs at better-characterized, shallower TCE sites. Additional characterization of subsurface source areas would be needed to limit the chance of contaminant concentration “rebound” and to maximize source remediation.

Site-specific engineering features need to be better understood before selecting a specific reagent for the Site. However, in-situ treatment is not limited to application in source areas and can be effective in reducing dissolved-phase concentrations. There is a potential design-related tradeoff for this site between wide area application and focused, source-oriented injection well implementation. Remedial design will consider the possibility that naturally occurring constituents could be released from aquifer materials based on application of the in-situ reagent. These effects would tend to be at the leading edge of the treatment zone and would dissipate downgradient of the treatment zone and once treatment is ceased (very likely to be within existing AOPC footprint).

In-situ physical and chemical treatment technologies are most effectively applied to site areas where the highest concentrations of TCE have been observed, with the goal of reducing the potential for downgradient (in both a horizontal and vertical sense) migration of contaminants. For this assembly, the likely well array would be immediately upgradient of the suspected subsurface source in order for the reagent to mix and react with the highest levels of TCE contamination. Proximity of suspected source areas to an active runway creates logistical challenges in applying this remedy in AOPC 2. Consideration may have to be given to limited field activity windows (such as night-time drilling only) in order to obtain Federal Aviation Administration approval for the work. Applications of in-situ technologies to the perimeter of the plumes with the intention of treating the lowest concentrations would not be an efficient use of resources and would do little to meet any of the RAOs.

3.1.4.1 Assembly 4a – NaMnO_4 Oxidation of TCE

The chemical oxidants most commonly employed to date to cause the rapid and complete chemical destruction of VOCs include peroxide, ozone, and permanganate. These oxidants have been capable of achieving high (greater than 90 percent) treatment efficiencies for TCE, with very fast reaction rates (minutes). Permanganate is the most applicable oxidizer for this site because it is effective over a parts hydronium (hydrogen-ion concentration) (pH) range of 3.5 to 12, while the typical groundwater pH range is between 7 and 8 at the Site.

3.1.4.2 Assembly 4b – ZVI Dechlorination of TCE

Nanoscale ZVI, usually granular iron, is a bulk reducing agent that has been traditionally used to dechlorinate TCE, thereby destroying its toxicity. It is currently believed that the iron surfaces become covered with precipitates of oxides (or carbonates and sulfides) that facilitate dechlorination. Recently, nanometer-sized iron has been effectively deployed as a slurry treatment in aquifers.

3.2 ALTERNATIVES ASSEMBLY AND PRELIMINARY EVALUATION

3.2.1 Alternative I – No Action

The No-Action alternative is required by CERCLA for the purpose of comparison to all other alternatives. Thus, there are no assemblies in the No-Action alternative. For groundwater, this alternative is retained as the baseline for the comparison of alternatives in chapter 4. It should be noted that there are current ongoing actions for short-term protection (point-of-use or household filters), and that several prior interim actions (e.g., tank and vault removals) have occurred. Selection of the No-Action alternative as the preferred alternative by USEPA would not rescind prior construction actions; however, it would entail ceasing the provision and maintenance of point-of-use filters in future.

3.2.2 Alternative II – Basic Action

Assemblies. All Assembly 1 elements (1a – 1e) are included in the Basic Action Alternative and will be applied in various combinations to both AOPCs and to both Priest Rapids-Roza 1 and Roza 2 aquifers therein.

Effectiveness. This alternative applied alone would only address RAO 1 (prevent exposure to contaminated groundwater). This alternative has both short- and long-term components to ensure meeting RAO 1. The alternative has been assembled in such a way as to combine the tools available to best meet Site needs in order to prevent exposure to contaminated groundwater.

Implementability. The alternative is technically implementable. There is uncertainty regarding administrative feasibility, with respect to the unknown willingness or capability of regulatory authorities in the CML, Grant County, and Washington Departments of Health and Ecology, to enforce some of the ICs, such as requirements for well testing. This uncertainty is expected to be reduced during the public review process of the Proposed Plan; based upon response by the aforementioned parties to USEPA. It is assumed, based upon the limited extent of the Site that is

outside the UGA and the likelihood of future extension of City or other-purveyor water supply, that some of the more legally rigorous control measures, such as covenants or State use restrictions, may be needed. Also, some of the ICs are "soft" ones, without enforcement provisions, inasmuch as they rely for effectiveness on information brochures and education. With these caveats, the alternative is considered to be implementable.

Cost. Capital costs for Basic Action are estimated at \$4,900,000. Periodic and O&M costs are estimated at \$11,200,000 for applicable components. The total estimated present value cost of this alternative is \$7,900,000.

Conclusion. Alternative II will be advanced for detailed analysis for both AOPCs and both aquifers (Priest Rapids-Roza 1 and Roza 2).

3.2.3 Alternative III – Basic Action Plus Groundwater Extraction and Ex-Situ Treatment

Assemblies. 1+3 (either 3a or 3b, activated carbon or air stripping, respectively).

Effectiveness. This alternative will meet RAOs 1 and 2 (prevent exposure to contaminated groundwater and minimize horizontal and vertical extents of groundwater contaminant plumes exceeding PRAGs). However, since the broad groundwater area (which may not include the source) is treated, this alternative may not meet RAO 3 (reduce further migration of contaminants from source materials to groundwater). Because of this, it is not certain that long-term attainment of RAO 2 will continue should treatment cease. That is, "rebound" could occur from an untreated source.

Implementability. The alternative is implementable. If air stripping were to be selected, a new-source evaluation for air and T-BACT may be required (WAC 173-460) to assure substantial compliance with air regulations with or without vapor treatment, depending on a final design. This is not expected to be problematic, based upon experiences at other sites with higher concentrations of TCE.

Cost. The estimated costs are represented by the combined capital and O&M costs from all four areas of treatment (AOPC 1 and 2, Priest Rapids-Roza 1 and Roza 2). The costs are based on the use of activated carbon as the ex-situ treatment method (Alternative IIIa). Basic Action capital costs are estimated at \$4,900,000, periodic and O&M costs are estimated at \$11,200,000, resulting in a present value cost of \$7,900,000. Further costs for this alternative, as applied to the individual AOPCs, are based on the individual assembly costs for each AOPC as follows:

- AOPC 1 Priest Rapids-Roza 1. Capital costs, \$940,000. Periodic and O&M costs, \$2,000,000. Total present value cost for 30 years, \$1,800,000.
- AOPC 1 Roza 2. Capital costs, \$1,200,000. Periodic and O&M costs, \$1,900,000. Total present value cost for 30 years, \$2,000,000.
- AOPC 2 Priest Rapids-Roza 1 Main Plume (MP). Capital costs, \$1,700,000. Periodic and O&M costs, \$3,400,000. Total present value cost for 30 years, \$3,200,000.
- AOPC 2 Priest Rapids-Roza 1 Northeast Plume (NEP). Capital costs, \$1,000,000. Periodic and O&M costs, \$2,400,000. Total present value cost for 30 years, \$2,000,000.

- AOPC 2 Roza 2. Capital costs, \$1,300,000. Periodic and O&M costs, \$1,900,000. Total present value cost for 30 years, \$2,100,000.

Actual costs will have to be summed at the selection of the alternative, where the Basic Action cost is accounted for one time and summed with the individual assembly costs. If the Basic Action components and Alternative III were to be applied to all five treatment areas, the total estimated present value would be \$18,900,000.

Conclusion. Alternative IIIa is advanced for detailed analysis for both AOPCs and both aquifers (Priest Rapids-Roza 1 and Roza 2). However, the final selection of the preferred ex-situ treatment would be made during the remedial design phase.

3.2.4 Alternative IV – Basic Action Plus In-Situ Groundwater Treatment

Assemblies. 1+4 (either 4a – NaMnO₄, or 4b – nanoscale ZVI).

Effectiveness. Alternative IV will meet RAOs 1 and 2 (prevent human exposure to contaminated groundwater, minimize horizontal and vertical extents of groundwater contaminant plumes exceeding PRAGs). As with Alternative III, since the sources are not treated directly, this alternative may not meet RAO 3, as it does not markedly affect further migration of contaminants from source materials to groundwater. Because of this, it is not certain that long-term attainment of RAO 2 will continue should treatment cease. Based on current information, this alternative may be more effective for meeting RAO 2 in AOPC 1 than in AOPC 2, due to the smaller treatment zone near the suspected source area associated with Site 20 (South Base Dump). Presuming source areas can be better determined and the efficiency of the treatment optimized, RAO 1 (prevent exposure to contaminated groundwater) would be met in the short term. RAO 2 (minimize horizontal and vertical extents of groundwater contaminant plumes exceeding PRAGs) would be met to a lesser degree in the short term than the longer term, since the down-plume water quality would primarily rely on admixture of clean, treated water with untreated water to reduce concentrations.

Implementability. The alternative is implementable. For ZVI, there is a technical note that high dissolved oxygen levels in site groundwater could reduce the effectiveness of the injected iron, which reacts with oxygen as well as TCE. However, the high oxygen concentration may be accounted for in system design.

Cost. The estimated costs are represented by the combined capital and O&M costs from all four areas of treatment (AOPC 1 and 2, Priest Rapids-Roza 1 and Roza 2). For this alternative, O&M costs were calculated assuming one application of the reagent per year for 30 years in each treatment area to account for the potential for “rebound” within a treatment area. For Alternative IVa, NaMnO₄ is the reagent and the estimated average cost is comparable to ZVI. Basic Action capital costs are estimated at \$4,900,000, periodic and O&M costs are estimated at \$11,200,000, resulting in a present value cost of \$7,900,000. Costs for this alternative as applied to the individual AOPCs are based on the individual *assembly* costs for each AOPC as follows:

- AOPC 1 Priest Rapids-Roza 1 Assembly 4. Capital costs, \$850,000. Periodic and O&M costs, \$13,000,000. Total present value cost for 30 years, \$6,300,000.

- AOPC 1 Roza 2 Assembly 4. Capital costs, \$700,000. Periodic and O&M costs, \$6,700,000. Total present value cost for 30 years, \$3,400,000.
- AOPC 2 Priest Rapids-Roza 1 MP Assembly 4. Capital costs, \$4,900,000. Periodic and O&M costs, \$60,000,000. Total present value cost for 30 years, \$29,000,000.
- AOPC 2 Priest Rapids-Roza 1 NEP Assembly 4. Costs not calculated for this area.
- AOPC 2 Roza 2 Assembly 4. Capital costs, \$2,100,000. Periodic and O&M costs, \$30,000,000. Total present value cost for 30 years, \$14,000,000.

Actual costs will have to be summed at the selection of the alternative, where the Basic Action cost is accounted for one time and summed with the individual assembly costs. If the Basic Action components and Alternative IV were to be applied to four of the five treatment areas, the total estimated present value would be \$60,900,000.

Conclusion. Alternative IVb (ZVI as in-situ reagent) will be advanced for detailed analysis for both AOPCs and both aquifers (Priest Rapids-Roza 1 and Roza 2). In actuality, however, the final selection of the best in-situ treatment would be made during the remedial design phase for a particular treatment area.

3.2.5 Summary of Alternatives

Table 3.2-1, *Remedial Alternatives*, and figure 4.2-1 summarize the alternatives, their targeted RAOs, and their areas of application.

CHAPTER 4
Detailed Analysis of
Alternatives

CHAPTER 4. DETAILED ANALYSIS OF ALTERNATIVES

The analysis of alternatives consists of the evaluation of and comparison of the remedial alternatives determined in chapter 3 to provide decision-makers with sufficient information to select an appropriate remedy to meet the CERCLA remedy selection requirements (USEPA, 1988). During the detailed analysis, each alternative is evaluated against seven of the CERCLA criteria, as described in section 4.1, and the general evaluation of the four alternatives against those criteria is in section 4.2. The results of the evaluations are used in section 4.3 to compare the alternatives to each other, generally and for each treatment area, and to identify the key tradeoffs. In section 4.4, the comparison of the alternatives against each other is summarized and a recommended alternative for each treatment area is presented. In section 4.4, the comparison of the alternatives against each other is summarized, and the alternative ranked “most favorable” for each treatment area is presented.

4.1 EVALUATION CRITERIA

To address CERCLA requirements, nine evaluation criteria were developed by the USEPA (USEPA, 1988). The first two criteria are the “threshold” factors; these criteria are:

- Protection of human health and the environment.
- Compliance with ARARs.

Five “primary balancing” criteria are then used to evaluate and identify the major tradeoffs amongst the remedial alternatives. The evaluation includes the following balancing criteria:

- Short-term effectiveness.
- Long-term effectiveness and permanence.
- Reduction of toxicity, mobility, or volume through treatment.
- Implementability.
- Cost.

The remaining two criteria are “modifying” factors, and are to be evaluated in the final ROD. The evaluation of these two factors can only be completed after the CERCLA Proposed Plan is published for comment and the public comment period is completed. These modifying factors are:

- State acceptance.
- Community acceptance.

A more detailed discussion of the nine evaluation criteria is presented below. Each remedial alternative is evaluated in section 4.2 with respect to the first seven criteria.

4.1.1 Protection of Human Health and the Environment

Remedial actions must be protective of human health and the environment (USEPA, 1988). Should the alternative not be deemed protective, then it cannot be selected as the preferred alternative. Each alternative is evaluated on its potential to limit exposure risk to humans and the environment during and after implementation of the remedial action. Alternatives providing the most short- and long-term protection of human health and the environment are considered more desirable. Risks associated with construction and management of wastes generated during remedial actions will be considered in the evaluation under this criterion. In this FS, this criterion corresponds to RAO 1 (prevent human exposure to contaminated groundwater).

4.1.2 Compliance with ARARs

Potential ARARs and TBCs at the Site for groundwater were identified in chapter 2 and are categorized based upon whether the requirement specifically addresses a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. The identification and selection of potential ARARs and TBCs assists in evaluation of potential remedial alternatives by providing the necessary actions at the Site. Alternatives must comply with ARARs or they cannot be considered for remedy selection unless an ARAR waiver can be justified in accordance with 40 CFR 300.430(f).

As noted in chapter 3, TCE source treatment is considered uncertain due to lack of accurately knowing the location of subsurface TCE sources despite an intensive effort to locate these sources. For this reason, none of the alternatives may comply with the SDWA MCL attainment requirement throughout the aquifers cited in CERCLA. A preliminary compliance line defined in effect by the treatment process location has been used (as described below) to assure protectiveness. USEPA may suggest a provisional compliance line to address the situation.

4.1.3 Short-Term Effectiveness

Short-term effectiveness for an alternative refers to its effect on human health and the environment during implementation of the remedial action, until RAOs are met. This criterion consists of the consideration of the estimated timeframe required to achieve RAOs, the short-term reliability of the technology, and protection of the community and workers during remediation.

In this FS, the attainment of RAO 2 (minimize horizontal and vertical extents of groundwater contamination plumes exceeding PRAGs) will be used to evaluate and compare short-term effectiveness. Attainment of RAO 1 is also a component of short-term effectiveness, but protection is a threshold criterion, and comparing the short-term effectiveness for an alternative presumes that RAO 1 is also met in the short term. The RAO 2 timeframe is based on the remedial technology considered and estimated by calculating the time after system startup for treated water flowing downgradient from a treatment area to reach the current plume boundary (i.e., the AOPC boundary set by 5 µg/L). The estimated time may vary based on the technology selected. Figure 2.2-1 shows the current plume delineation for AOPCs 1 and 2. While this was

set by the Priest Rapids-Roza 1 aquifer concentrations, as discussed in chapter 1, it is the best available picture of the limits of the Roza 2 as well, and sets the limits there as well.

4.1.4 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence criterion evaluates the ability of an alternative to prevent or minimize risk to public health and the environment after RAOs have been met. Components considered when evaluating the long-term effectiveness and permanence of an alternative include examining the magnitude of residual risk and the adequacy and long-term reliability of controls that may be required to manage this residual risk (USEPA, 1988). Residual risks may include the risks posed by treatment residuals and/or untreated residual contamination. Information from similar sites with similar contaminants may be considered in evaluating the adequacy and/or reliability of controls for an alternative.

In this GWFS, long-term effectiveness and permanence considers site conditions after the attainment of RAOs 1 and 2 and considers the possibility of attaining RAO 3 – prevent or minimize further migration of contaminants from source materials to groundwater. The residual risk has been approximated for the sake of this analysis by the quantity of TCE-contaminated water left in the aquifers following attainment of RAO 2.

4.1.5 Reduction of Toxicity, Mobility, or Volume through Treatment

USEPA has a statutory preference for selecting remedial actions that employ treatment technologies to permanently and significantly reduce toxicity, mobility, or volume of hazardous substances as their principal element (USEPA, 1988). Treatment technologies that focus on the destruction of toxic contaminants, the reduction of the total mass of toxic contaminants, the irreversible reduction in contaminant mobility, or the reduction of total volume of contaminated media are desired. Factors to be considered are the treatment processes; amount of hazardous materials to be destroyed or treated; order of magnitude expectation of overall reduction in toxicity, mobility, or volume; the degree to which the treatment will be irreversible; type and quantity of residuals that will remain after treatment; and whether the alternative would treat the principle threat. These factors may be considered individually or combined for overall reduction when comparing alternatives.

Based on the above considerations, for this Site, the effectiveness of each alternative in reducing toxicity, mobility, and volume is evaluated by assessing its ability to: (1) Reduce contaminated volume by assessing the proportion of the contaminant plume remediated compared to the original plume projection; (2) reduce contaminant concentration in AOPCs; and (3) reduce source contribution to dissolved-phase plumes. An assumption of “rebound” upon cessation of a remedial alternative’s treatment is required given the lack of knowledge of source and inability to target source of TCE.

4.1.6 Implementability

Implementability is used as a measure of both the technical and administrative feasibility of constructing, operating, and maintaining a remedial action alternative (USEPA, 1988). Technical feasibility refers to the following factors:

- Ability to reliably construct, operate, and maintain the components of the alternative during remediation and after completion, as well as the ability to meet applicable technical regulatory requirements.
- Likelihood that technical problems associated with implementation will lead to schedule delays.
- Ability of remedial equipment to undertake additional remedial actions (e.g., increased flows or volumes) and/or phase in other interim remedial actions, if necessary.
- Ability to monitor the effectiveness of the implemented remedies.

An example of a potential implementation issue regarding attainment of RAO 2 could be the groundwater extraction and ex-situ treatment of two aquifers located in the same AOPC. Extraction from either aquifer would likely vary hydraulic head in both. This in turn could alter migration pathways and diminish the effectiveness of extraction for one or both aquifers.

Administrative feasibility includes the following criteria:

- Ability to get approvals from appropriate agencies to implement the alternative.
- Availability of support services for the treatment, storage, and disposal of generated wastes.
- Availability of specialized equipment or technical experts to support the remedial actions.

4.1.7 Cost

Both capital and O&M costs are evaluated for each alternative. Capital costs include design costs, equipment costs, construction costs, and other relevant short-term expenditures associated with the installation of the remedial action components. O&M costs include the expenses associated with equipment maintenance and repair, site and equipment monitoring, power, chemicals, and disposal of residues. Periodic costs associated with the administration and remedial action operation were calculated separately from the O&M costs.

Cost is used to identify and eliminate alternatives that are significantly more expensive than others without proportional benefits or to assist choice among several alternatives offering similar protection to human health and the environment. The “FS-level” costs in this document are estimated to be within the USEPA RI/FS guidance range of +50 percent to -30 percent when compared to actual project costs after the remedial design phase. The main components of each alternative are sized prior to developing the cost estimates. Sizing is based on general guidelines found in technical literature, past experience, and general professional judgment. For the cost estimation process, data are gathered from cost proposals provided by subcontractors for each remedial alternative, prior expenses, and professional judgments. The level of detail is similar in all of the alternatives to avoid comparing estimates having different levels of accuracies. The RACER™ 2005 (Remedial Action Cost Engineering and Requirements) program by Earth-Tech, Inc. was used for cost estimates.

For fair cost comparison, capital costs are assumed to be entirely expended in year zero (0), even though some alternatives may take longer to implement than others. Because expenditures occur

over different periods of time in some of the alternatives, O&M and periodic costs are discounted to a common base year (i.e., year zero) and added to the capital costs to obtain the total present worth of each alternative. With present worth analysis, alternatives can be compared based on a single value. The present worth analysis relies on a selected discount rate that represents the rate of return on an annuity investment minus the inflation rate. Following USEPA guidelines for cost estimating in FSs (USEPA, 1993 and 2000a), a discount rate of 7.0 percent is appropriate for this Site, because it is no longer a Federal facility.

In accordance with 40 CFR 300.430 (f)(1)(ii)(D), cost-effectiveness is determined by first evaluating overall effectiveness based on the three balancing criteria of short-term effectiveness; long-term effectiveness and permanence; and reduction of toxicity, mobility, or volume through treatment. Overall effectiveness of an alternative is then compared to its cost to determine if its costs are proportional to its overall effectiveness. Cost estimates are intended to provide a basis for alternative evaluation and comparison purposes only and should not be used for future budgeting, bidding, or construction purposes. Detailed cost analysis tables are presented in appendix F.

4.1.8 State Acceptance

This assessment will be performed by USEPA during the Proposed Plan, public comment process, and ROD. It will incorporate the State's technical and administrative input regarding each of the remedial alternatives. For this site, the State is represented by Ecology. The factors to be evaluated include features of the actions that the State supports, has reservations about, or opposes.

4.1.9 Community Acceptance

This assessment will be performed by USEPA during the Proposed Plan, public comment process, and ROD. It will incorporate public input into the analysis of the remedial alternatives. Factors of community acceptance include features of the support, reservations, and opposition of the community. During the RI phase of this project, USACE established a Restoration Advisory Board in 1999 that was active through 2004. USEPA Region 10 has continued the Community Relations Plan through present.

4.2 EVALUATION OF REMEDIAL ALTERNATIVES

In this section, the remedial alternatives identified in chapter 3 are evaluated using the first seven criteria described in section 4.1. Evaluations of the last two criteria (i.e., State and community acceptance) are deferred to the ROD following receipt of State and public comments from the Proposed Plan process.

Figure 4.2-1 illustrates how the alternatives developed in section 3 derive from RAOs, the GRAs, the technologies that comprise the GRAs, and the assemblage of technologies that comprise the four alternatives selected for evaluation. The figure summarizes the selected RAOs to the selected process options, in preparation for the assembly of alternatives, and each medium of concern is shown with RAOs, GRAs selected to meet RAOs, selected remedial technologies within the GRAs, and selected process options within the selected technologies.

The following sections highlight the selected process options and technologies for assembly of alternatives as detailed in table 2.6-1. However, the following paragraphs only discuss the actionable process options and technologies. As stated in previous sections and tables, "No Action" is the only option retained for subsurface soils because no actionable area has been identified and is retained for groundwater as a baseline for comparison once all other alternatives are assembled. The alternative ranked as "most favorable" for each treatment area will be shown at the conclusion of the detailed analysis, in section 4.4. Use of differing remedial actions are considered for different treatment areas at the Site. Alternative I applies to all the AOPCs/aquifers; Alternative II applies to all or to a subset of these. Alternatives III and IV apply to each area considered for treatment.

The detailed analysis of alternatives discusses advantages and disadvantages of each alternative. The evaluations incorporate information obtained from technology vendors, technology reports and articles, and other related publications.

The Site investigations suggest five prospective groundwater treatment areas within the two AOPCs and two aquifers Priest Rapids-Roza 1 and Roza 2. AOPC 2 appears to have two distinct plumes, as may be seen in figure 2.2-1. The evaluation of alternatives considers five groundwater treatment areas; two are in AOPC 1 and three in AOPC 2. These are described in the following sections.

4.2.1 AOPC 1 Groundwater Treatment Areas

- AOPC 1 Priest Rapids-Roza 1 is the southerly plume (see figure 2.2-1), which consists of the groundwater in the upper fractured basalt aquifer, extending from Site 20 (South Base Dump) approximately 7,000 ft south-southwest. It encompasses monitoring well 04-BW09 in the northeast and domestic wells WP-22, WP-15E, and WP-15W in the southwest. TCE concentrations within AOPC 1 Priest Rapids-Roza 1 range from 88 µg/L to 5 µg/L.
- AOPC 1 Roza 2 is the southerly plume, which consists of the groundwater in the next lower fractured basalt aquifer (from Priest Rapids-Roza 1), with the same areal extent as defined for Priest Rapids-Roza 1. TCE concentrations in AOPC 1 Roza 2 range from 1 to 30 µg/L.

AOPC 1 includes unincorporated urban residential land, urban residential land incorporated into the CML, and urban commercial/industrial zoning, all within the UGA (figure 2.2-1). The highest levels of contamination are within the commercial/industrial zone, although the greater areal extent of contamination is in the urban residential area. With respect to potential exposure to contaminated groundwater within this AOPC, the current likelihood of exposure is relatively low because the majority of the urban residential area is serviced by the CML water system or other local water purveyors (figures 1.3-1 and 1.3-2) that obtain water from unaffected aquifers. Additionally, based on Washington State Ecology water resources information, approximately five drinking water supply wells (individual residential and Group B wells) are within AOPC 1 and the aquifers of concern. AOPC 1 appears to affect more residential water supplies than does AOPC 2. It is anticipated that land-use activities will conform to Grant County zoning into the foreseeable future.

The surface area comprising AOPC 1 is estimated at approximately 16 million square ft (about 0.57 square mile; 370 ac). This AOPC is a surface projection onto both the Priest Rapids-Roza 1 and the Roza 2 aquifers. The alluvial aquifer (approximately 80 – 135 ft bgs) is not known to have TCE exceeding the PRAG. Extent of potential migration of TCE to aquifers below Roza 2 aquifer is currently unknown. The volume of potential concern for Priest Rapids-Roza 1 is 720 million cubic ft based on an average aquifer thickness of 45 ft. The estimated volume of potential concern for Roza 2 is 400 million cubic ft based on an estimated average aquifer thickness of 25 ft.

Based on the pattern of concentrations of dissolved TCE, the former South Base Dump, Site 20, is believed to have been the probable historic primary source of TCE contamination in AOPC 1. Surface soil data for Site 20 (described in the SSFS) do not indicate a current TCE source, but may suggest a secondary source either in the aquifer or in the deeper unsaturated soil. Alternately, multiple secondary sources in AOPC 2 may have contributed to groundwater contamination. To date, investigations have been unable to pinpoint the exact location or nature of a subsurface TCE source in either AOPC.

For the detailed analysis, design assumptions were made based on available information. In estimating the extent of TCE contamination in the Roza 2 aquifer, the areal extent is assumed the same as in the better-understood Priest Rapids-Roza 1 aquifer. Dissolved concentrations of TCE in Roza 2 are based on the observed values. To produce an FS-level cost estimate, it was assumed that dissolved concentrations do not represent the entire TCE inventory in groundwater. Presence of inferred sources would increase the TCE inventory above that which could be calculated from dissolved concentrations alone. These sources could renew the dissolved concentrations as they are depleted. Moreover, the estimate of the extent of Roza 2 above the PRAG is uncertain. Where corresponding Priest Rapids-Roza 1 and Roza 2 concentrations are known, the Priest Rapids-Roza 1 concentrations are higher and appear to occupy more area.

4.2.2 AOPC 2 Groundwater Treatment Areas

AOPC 2 is more complicated than AOPC 1 due to the existence of two plumes that merge into one in Priest Rapids-Roza 1.

- AOPC 2 Priest Rapids-Roza 1 MP is the larger or main portion of the northerly plume (see figure 2.2-1), and consists of the groundwater in the upper fractured basalt aquifer. Most-recently measured TCE concentrations within AOPC 2 Priest Rapids-Roza 1 MP range from 5 to 41.4 µg/L. The northwest portion of the plume starts near Site 33 (the dump at the end of the southeast runway) and extends approximately 6,000 ft south-southwest.
- AOPC 2 Priest Rapids-Roza 1 NEP is the smaller, northeast portion of this plume, and extends from approximately 500 ft southwest of Site 21 (the Larson Waste Water Treatment Plant) 2,500 ft in a south-southwest direction. This treatment area has substantially lower concentrations of TCE (5 to 14 µg/L, with well 99-BW15 having a stable concentration between 10 and 14 µg/L). There is no extant information on Roza 2 in this treatment area. Priest Rapids-Roza 1 concentrations are lower than elsewhere in the Site in Priest Rapids-Roza 1, and Roza 2 would likely be lower still. Alternatives II,

III, and IV include new Roza 2 monitoring wells to determine need for deeper treatment, but no deeper treatment area is proposed in this GWFS.

- AOPC 2 Roza 2 is in the northerly plume, and consists of the groundwater in the upper fractured basalt aquifer, within the footprint defined by AOPC 2 Priest Rapids-Roza 1 MP. Only one Roza 2 well falls within the area of AOPC 2. The concentration in that well (04-CW03) was around 22 µg/L in 2004.

AOPC 2 consists of the more northerly groundwater plumes impacted with TCE greater than (or equal to) the PRAG of 5 µg/L. The areal extent of AOPC 2 includes a segment of rural residential land outside of the UGA, Port of Moses Lake property (GCIA) and urban commercial/industrial within the UGA (figure 2.2-1). The downgradient edge of the AOPC is near the perimeter of urban residential zoning (see figure 2.2-1), although it has been noted in previous sections that there is some uncertainty associated with the delineation of the downstream edge of the plume. Thus, attainment of RAO 2 for the MP is expected to happen soon after remediation starts if it has not already been attained. The highest levels of TCE contamination for either Priest Rapids-Roza 1 or Roza 2 within this AOPC are within Port of Moses Lake property. Likelihood of exposure to contaminated drinking water is low due to the land use over most of the plume. In the residential area downgradient of the estimated southern end of AOPC 2, City water is provided, although there could be individuals still relying on domestic wells. There are homes with private drinking water wells within the AOPC currently on the whole-house filter program being administered by USACE, and it is not deemed reasonable to put these homes onto distributed water due to zoning restrictions and lack of other purveyors in the area. For the areas within Port property and the commercial/industrial zone, the potential for exposure to contaminated groundwater is reduced due to Port, State, and local jurisdictional requirements for new wells and water-use restrictions. As with AOPC 1, land-use activities are anticipated to remain unchanged into the near future based on Grant County zoning information.

The surface area comprising AOPC 2 is estimated at approximately 14 million square ft (approximately 0.50 square miles, 320 ac; this estimate is the sum of two areas in the AOPC in which PRAG is exceeded for TCE). It is important to note that stable AOPC footprint applies to the projection onto the surface that covers the groundwater within the Priest Rapids-Roza 1 and Roza 2 aquifers. The alluvial aquifer (approximately 80 – 135 ft bgs) is not known to have TCE above the PRAG (with the exception of one detection in alluvial well 00-AW11 at 5.1 µg/L.). Extent of potential migration of TCE below the Roza 2 aquifer is unknown at present. The estimated volume of potential concern for Priest Rapids-Roza 1 is 630 million cubic ft based on an estimated average aquifer thickness of 45 ft. The estimated volume of potential concern for Roza 2 is 350 million cubic ft based on an estimated average aquifer thickness of 25 ft. Other general aquifer characteristics were described in chapter 1.

Unlike AOPC 1, where a subsurface source location may be attributed to a single location, the sources for AOPC 2 are more difficult to locate with the same level of confidence, and may be numerous, dispersed sources. The area within AOPC 2 most likely to receive groundwater treatment is the area associated with the former landfills (sites 8, 31, and 33). Although groundwater TCE data are the highest within and near these sites, they cover a large area, and previous investigations in the RI/BRA were unable to identify a current source there. Not being

able to better define the area of greatest contribution of TCE to groundwater affects both ex-situ and in-situ treatment designs with respect to number and placement of wells.

4.2.3 Evaluation of Remedial Alternatives

In this section, application of an alternative is described for the specific treatment area, as well as common design aspects relevant to the evaluation. FS-level design parameters, such as number of wells and flow rates, for each treatment area are shown in table 4.2-1. The general evaluation of each alternative against the seven CERCLA criteria is found in table 4.2-2. The cost analysis for each alternative for each treatment area used in the evaluation and detailed analysis is shown in table 4.2-3.

4.2.3.1 Alternative I - No Action

Alternative I is required by the NCP. This alternative provides a baseline for the comparison of active remedial alternatives developed. Under the "No-Action" Alternative, institutional controls are not implemented, and remediation and monitoring of groundwater contamination are not conducted. The No-Action Alternative also does not address migration of contaminants from the vadose zone to groundwater.

This alternative would discontinue the current whole-house filter program and Site monitoring. At a minimum, CERCLA requires administrative reassessments every 5 years whenever contaminants are left in place, and if the Site is not open for unrestricted use, this requirement applies to this Site.

Table 4.2-2 summarizes the evaluation for each alternative in general and in particular for each assembly (e.g., addition of extraction/ex-situ treatment to the basic protection package) for each treatment area and aquifer. Evaluation of Alternative I against the seven criteria follows.

- Overall Protectiveness. Alternative I is protective of the environment, because no ecological receptors have been identified and risk estimates do not exceed the CERCLA risk range; however, it is not protective of human health due to exceedance of the MCL for TCE.
- Compliance with ARARs. Alternative I does not meet ARARs. Contaminant concentrations are assumed to remain at current levels, and at those levels exceed the PRAG of 5 µg/L TCE.
- Short-Term Effectiveness. Does not meet any RAOs. No protective measures are implemented. The magnitude of the residual risk is worse from current values due to the cessation of existing exposure-protective measures. RAO 2 is not met in this alternative because no action would occur to restrict the contamination in any aquifer. Although the plumes are relatively stable, there is no indication that the existing TCE patterns will diminish without active intervention.
- Long-Term Effectiveness and Permanence. Does not meet RAOs 2 or 3. The current area of both AOPCs comprises an area of about 690 ac. Neither AOPC size would be reduced under Alternative I. Currently, the plumes appear to be stable, suggesting that the boundaries of the AOPCs are in a steady state between inputs to the groundwater

from the sources and physical advection/dispersion of water as it flows downgradient, diluting and attenuating the concentrations. The time to meet these RAOs is too long to estimate.

- Reductions in Toxicity, Mobility, and Volume through Treatment. The no-action alternative does not include any treatment, and therefore does not reduce the toxicity, mobility, or volume of the TCE in the groundwater at the Site.
- Implementability. The No-Action alternative is implementable, although cessation of current whole-house filter programs might be problematic.
- Cost. The No-Action alternative includes costs for 5-year reviews required due to hazardous substances remaining at the Site. The estimated present value costs for No Action as applied to all AOPCs and aquifers combined are estimated to be \$97,000 for the 30-year timeframe used in the estimate.

Advantages and disadvantages of this alternative.

- Disadvantage. This alternative does not pass the threshold criteria and is only included in this FS as a CERCLA requirement.

4.2.3.2 *Alternative II – Basic Action Only*

As described in section 3.1.1, this alternative constitutes a variety of options for assuring that RAO 1 (only) is met, so that the public is not exposed to levels of TCE above the PRAG of 5 µg/L. The elements include ICs, alternate water supplies such as new wells or point-of-use filters, and long-term monitoring. A catalog of potential ICs is presented in table 4.2-4. Alternative II long-term monitoring program is based on existing wells with additional wells in key aquifer locations. Long-term monitoring also includes monitoring for acetone at well 02-BW02 to determine whether the observed exceedances will dissipate.

Because Basic Action is also a part of Alternatives III and IV, the following evaluation is generally applicable to those other alternatives as well, except that treatment options provide the means of meeting additional RAOs. Accomplishment of RAO 2, that is, constraining the contaminated groundwater to areas that where residential well placement is prohibited, could in time reduce the need for some of the Alternative II actions downgradient of the controlled areas.

Table 4.2-1 describes details for the implementation of this alternative, including numbers of estimated water and sewer connections, point-of-use (wellhead or whole house) filters, monitoring wells, and fencing. Table 4.2-2 summarizes the evaluation for each general alternative.

- Overall Protectiveness. Meets RAO 1 only. It is protective of human health and the environment to prevent public exposure to TCE above the PRAG to the extent that the measures herein can be applied in the areas of concern. If RAO 1 is applied fully, no unacceptable short-term exposures or cross-media impacts would occur. This GWFS has identified a library of IC measures; selection of specific ones for specific areas will be determined by USEPA in the ROD. The adequacy and reliability of the controls to prevent exposure to contamination are subject to periodic review and change

if warranted. Because hazardous substances remain onsite, 5-year reviews are required to assess effectiveness of IC measures, alternate water supply and individual well treatment systems, and long-term monitoring of groundwater.

- Compliance with ARARs. Does not meet ARARs. Alternative II assumes the aquifer contaminant concentration levels remain at current levels; accordingly, the PRAG value will continue to be exceeded within current AOPCs.
- Short-Term Effectiveness. Meets RAO 1 but not RAO 2. The alternative would prevent public exposure to groundwater with TCE over the PRAG (RAO 1). These controls and measures would need to be continued into the indefinite future in order to ensure that new exposures do not occur. Also, such controls require detailed coordination between Federal, State, and local agencies and regular plan monitoring to ensure success of ICs.
- Long-Term Effectiveness and Permanence. The areas of the plumes comprise an area of about 690 ac. This would not be reduced under Alternative II. Because the plumes do not appear to be diminishing naturally, and because neither RAO 2 nor 3 is addressed, it is not possible to estimate the timeframe for when residual risks would permit removing all controls.
- Reductions in Toxicity, Mobility, and Volume through Treatment. The actions taken under Alternative II do not address the treatment of the principal threat in the groundwater.
- Implementability. All services and materials are readily available and obtainable. Technical and administrative feasibility difficulties for this alternative are associated with the ability to consistently implement ICs, difficulties in connecting water users existing (or future) water lines, O&M for individual well treatment, access to and sampling of long-term monitoring wells, and domestic well sampling as part of the alternative. Key concerns regarding the controls in the short and long terms for this alternative revolve around the following:
 - The public must be made aware of the potential risks related to withdrawing groundwater from the aquifers of concern within an area of concern through an education/notification program. Dissemination of information is critical in both short and long terms for this alternative.
 - Well-testing must occur to determine specific risk for those within the AOPC and aquifer of concern.
 - Individual well treatment installation and O&M of point-of-use filters would be required for residences known to be exposed to TCE-contaminated groundwater. For the public in affected residential areas, a clean long-term water supply is required.
 - For many of the elements within this alternative, implementation of measures may begin or be continued from existing programs almost immediately. Actions such as public notifications, permit requirements (by Ecology) for new wells, and provision (or continuation) of engineering controls with O&M would proceed as soon as practicable without awaiting a delay for remedial design. Some ICs require agency coordination. Some of the constructed elements, such as

extending water/sewage lines or new well installation, have remedial design components that will occur subsequently.

- Cost. The estimated present value for Alternative II applied site wide is \$7,900,000.

Advantages and disadvantages of this alternative:

- Advantage. Implementing many of the measures would actually be a continuation of existing programs resulting in a rapid achievement of RAO 1.
- Advantage. A cost benefit is applied for those areas where this alternative could be applied to a specific treatment area. The cost of the Basic Action would already be accounted for on a site-wide basis and therefore no additional costs would be incurred.
- Disadvantage. Alternative II would not be acceptable as a stand-alone, site-wide solution due to not meeting all ARARs and potential inconsistencies in application of engineering and ICs.

4.2.3.3 *Alternative III – Basic Action with Groundwater Extraction and Ex-Situ Treatment*

The actions included under the Basic Action component of this alternative are the same as those identified in section 4.2.3.2. The treatment portion details for the alternative for the groundwater extraction systems are based on a number of assumptions (see table 4.2-2 and appendix F) from interpretation of existing data. The extraction well layouts are illustrated in figure 4.2-2. The number of extraction wells takes into account capture zone analysis, well interference, and use of re-injection wells. Re-injection wells ensure water balance in the aquifer and minimize negative impacts on availability of groundwater downgradient. This alternative also requires additional site characterization specifically for pumping requirements and groundwater modeling for the remedial design.

The groundwater extraction and ex-situ treatment of both aquifers is based upon design option “C” (see chapter 3, figure 3.1-1) where extraction wells are located in the groundwater plume hotspot near the suspected source area, with the intent of isolating the source from the bulk of the dissolved-phase plume and allowing the dissolved-phase plume to attenuate with time.

The method of ex-situ treatment selected in chapter 3 was activated carbon with offsite treatment of the treatment media. One assumption made for this FS-level design was to locate the activated carbon treatment at the individual extraction wells. Anticipated TCE concentrations are amenable to treatment at each wellhead. Sizing of activated carbon systems is based on the expected flow rates and average TCE concentrations for conceptual extraction well locations.

A general evaluation of this alternative follows. Discussion of variations between different AOPCs and different aquifers follows in subsequent sections. See section 4.2.3.2 above for evaluation factors relating to the embedded Basic Action component.

- Overall Protectiveness. Meets RAOs 1 and 2, but not RAO 3. Alternative III is initially protective of human health and the environment during active remediation due to the Basic Action component. The attainment of RAO 2 offers the potential to reduce the scope of some protection measures in the remediated areas. Such measures would have

to be maintained in the long term. Because hazardous substances remain onsite, 5-year reviews are required to assess effectiveness

- Compliance with ARARs. Does not meet ARARs because not all of the aquifers are returned to concentrations below the PRAG of 5 µg/L. Meets RAOs 1 and 2, but significant uncertainty remains regarding the achievement of RAO 3 (prevent or minimize further migration of contaminants from source materials to groundwater) since the alternative is not likely to affect any subsurface TCE sources upgradient of the treatment area. The PRAG value will continue to be exceeded in an area within AOPCs. However, these areas may be defined and circumscribed by a compliance boundary.
- Short-Term Effectiveness. Meets RAOs 1 and 2. Because this alternative includes a treatment technology that addresses plume extent, its timeframe for achievement of RAO 2 can be evaluated. The timeframes for remediation of the downgradient plumes to meet RAO 2 vary by AOPC were estimated using simple groundwater flow velocity calculations. The time shown in the short-term effectiveness represents the time from system startup to the time that clean water flows past the farthest downgradient edge of the AOPC. Because this timeframe is estimated using general groundwater velocity, actual downgradient cleanup times may be longer than shown.
 - AOPC 1 Priest Rapids-Roza 1— 9 years.
 - AOPC 1 Roza 2 – 14 years.
 - AOPC 2 Priest Rapids-Roza 1 MP – 0 years (achieved close to time zero).
 - AOPC 2 Priest Rapids-Roza 1 NEP – 3 years.
 - AOPC 2 Roza 2 – 7 years.
- Long-Term Effectiveness and Permanence. Does not address source contamination, and so does not likely meet RAO 3. For this alternative to prevent “rebound” of TCE concentrations from the remaining source material, continuation of the system would be required until the groundwater source is depleted. Based upon current information, the treatment system would operate into the indefinite future. It is estimated that Alternative III would leave approximately 270 ac of groundwater contaminated above the PRAG in the footprint of both AOPCs. (This compares to 690 ac prior to the remediation.)
- Reductions in Toxicity, Mobility, and Volume through Treatment. The treatment in Alternative III addresses widespread contaminated groundwater and reduces the risk posed by that contamination. The method of treatment removes TCE from the groundwater, but physically binds it to activated carbon, which must be treated offsite. Typically, the TCE adsorbed to the carbon is off-gassed by heat and incinerated during regeneration of the carbon medium.

Table 4.2-1 shows the design elements for this alternative. Figure 4.2-2 shows comparison of the current plume delineation to the projected plume areas after the attainment of RAO 2. Alternative III would remove 96 percent of AOPC 1’s extent, and 52 percent of AOPC 2. Residual risks are managed by incorporation of Alternative II (Basic Action).

Note that in table 4.2-1, the total TCE mass removal from the treatment area appears to be significantly greater than the estimated value for the total for all aquifers shown in

table 1.5-3 (108 kg overall). The discrepancy in the numbers is because the latter estimate is based on dissolved concentrations only. Treatment calculations are based on continuous transfer from a source to dissolved phase and recognize the potential for a reservoir of concentrated TCE.

Because the treatment does not address the source directly, it is expected that concentrations downgradient of the treatment area would return to pre-treatment concentrations when the extraction and adsorption treatments cease.

- **Implementability.** Alternative III is technically and administratively feasible, based on experience with numerous groundwater extraction and treatment systems. The technology is generally available and has been sufficiently demonstrated to be applicable for this situation. The materials required for the treatment are readily available. The activated carbon may require temporary storage between change out and disposal/recycling. The systems may be adjusted after startup to account for site conditions.

A possible technical difficulty could arise due to concurrent extraction from hydraulically connected aquifers. It is possible to address head differences in aquifers during design.

The long expected period for treatment under this alternative requires system optimization and O&M to assure reliable and consistent performance. Groundwater extraction and treatment systems are typically maintenance intensive. This treatment also requires coordination with public and private landowners for access to lands for construction, substantial permit requirements, and to assure O&M is accomplished.

- **Cost.** The estimated present value cost for Alternative III applied to all five treatment areas is approximately \$18,900,000. The cost includes the total cost for Basic Action (Alternative II), as well. Costs for the alternative in each area are presented below.

Advantages and Disadvantages

- **Advantage.** Both a limited area subsurface source in AOPC 1 and numerous subsurface sources contributing to the contamination in AOPC 2 are addressed by this alternative.
- **Advantage.** Groundwater extraction with ex-situ treatment is a widely used technology with which considerable experience has been accumulated regarding remedial design and implementation.
- **Advantage.** The accomplishment of RAO 2 could reduce some of the ICs as plumes are limited to nonresidential and Port-owned areas, in which areas construction of new domestic wells and consumption of water may be avoided.
- **Disadvantage.** Alternative will not likely achieve RAO 3 due to the nature of the treatment technology. Greater groundwater extraction rates would not necessarily improve treatment efficiency.
- **Disadvantage.** The infrastructure would be left in place for an indefinite period.

Alternative III – AOPC 1

This and subsequent sections provide additional details for different AOPCs and aquifers' evaluations. If there are no differences from the general evaluation of the alternative, the topic is not repeated.

Table 4.2-2 contains FS-level design details. The layout for Alternative III extraction wells is shown in figure 4.2-2. Groundwater extraction would restrict contaminant input to the southwest of Site 20. Access to the Site and use of the land for the duration of the remedial action requires agreement from the current landowner. The treatment area is commercial/industrial and is currently lightly used.

Alternative III for AOPC 1 Priest Rapids-Roza 1

Additional Evaluation Criteria details.

- **Short-Term Effectiveness.** Time to accomplish RAO 2 is estimated to be 9 years. The time shown in the short-term effectiveness represents the time from system startup to the time that clean water flows past the farthest downgradient edge of the AOPC. Because this timeframe is estimated using general groundwater velocity, actual downgradient cleanup times may be longer than shown.
- **Long-Term Effectiveness.** Approximately 19 ac of contaminated groundwater would remain untreated within the footprint of this AOPC.
- **Reductions in Toxicity, Mobility, and Volume through Treatment.** Upon attainment of RAO 2, the plume will be reduced from current size by 96 percent.
- **Cost.** The separate assembly present value for treatment for AOPC 1 Priest Rapids-Roza 1 is estimated at \$1,800,000. This cost does not include the associated cost of the basic actions, and it should be used to compare against other assemblies for this AOPC/aquifer. (This comparison is done in section 4.3.)

Additional Advantages and Disadvantages.

- **Advantage.** There is evident connection between this aquifer and the Roza 2 aquifer, and reducing TCE dissolved concentrations in Priest Rapids-Roza 1 may reduce the lower aquifer's TCE contamination.

Alternative III for AOPC 1 Roza 2

Additional Evaluation Criteria details.

- **Short-Term Effectiveness.** Time for accomplishing RAO 2 is estimated to be 14 years. The time shown in the short-term effectiveness represents the time from system startup to the time that clean water flows past the farthest downgradient edge of the AOPC. Because this timeframe is estimated using general groundwater velocity, actual downgradient cleanup times may be longer than shown.

- Long-Term Effectiveness. Approximately 19 ac of contaminated groundwater would remain untreated within the footprint of this AOPC.
- Reductions in Toxicity, Mobility, and Volume through Treatment. Upon attainment of RAO 2, the plume will be reduced from current size by 96 percent (assuming the same contaminant limits used for AOPC 1 Priest Rapids-Roza 1).
- Cost. The separate assembly present value cost of treatment within Alternative III for AOPC 1 Roza 2 is estimated at \$2,000,000. This cost does not include the associated cost of the basic actions, and it should only be used to compare against other assemblies for this AOPC/aquifer. (See section 4.3.)

Additional Advantages and Disadvantages.

- Advantage. There is evident connection between this aquifer and the Priest Rapids-Roza 1 aquifer and cleanup of the upper aquifer may reduce Roza 2 TCE contamination.
- Disadvantage. Treatment options for this aquifer face greater technical challenges and costs due to the depth of treatment area.

Alternative III – AOPC 2

Groundwater extraction and ex-situ treatment in the MP of AOPC 2 address multiple suspected sources, cutting off the flow of contamination downgradient to the southwest. The FS-level layout (figure 4.2-2) of the MP includes extraction wells on the boundary of Port of Moses Lake property, where characterization, installation, access for maintenance, and ongoing commerce and activities are believed to be favorable. For the NEP, the layout includes two extraction wells in the northern portion of the plume to draw contaminated water away from residents.

Alternative III for AOPC 2 Priest Rapids-Roza 1 MP

Additional Evaluation Criteria details

- Short-Term Effectiveness. RAO 2 is virtually accomplished at this time, since the current plume project appears to be limited by the commercial industrial boundary. However, the time to draw the plume back to the treatment zone is estimated to be 3 years from system initiation. The time shown in the short-term effectiveness represents the time from system startup to the time that clean water flows past the farthest downgradient edge of the AOPC. Because this timeframe is estimated using general groundwater velocity, actual downgradient cleanup times may be longer than shown.
- Long-Term Effectiveness. Approximately 250 ac of contaminated groundwater would remain untreated within the footprint of this AOPC.
- Reductions in Toxicity, Mobility, and Volume through Treatment. Upon attainment of RAO 2, the plume will be reduced from current size by 47 percent.
- Cost. The separate assembly present value cost of Alternative III for AOPC 2 Priest Rapids-Roza 1 MP is estimated at \$3,200,000. This cost does not include the associated

cost of the basic actions, and it should be used to compare against other assemblies for this AOPC/aquifer. (This comparison is done in section 4.3.)

Additional Advantages and Disadvantages.

- Advantage. The numerous subsurface sources contributing to the contamination in AOPC 2 are addressed by this alternative.

Alternative III for AOPC 2 Priest Rapids-Roza 1 NEP

Additional Evaluation Criteria details.

- Short-Term Effectiveness. Time to accomplish RAO 2 is estimated to be 2.5 years. The time shown in the short-term effectiveness represents the time from system startup to the time that clean water flows past the farthest downgradient edge of the AOPC. Because this timeframe is estimated using general groundwater velocity, actual downgradient cleanup times may be longer than shown.
- Long-Term Effectiveness. Although the upgradient plume is not well defined, approximately 11 ac of contaminated groundwater would remain untreated within the footprint of this AOPC.
- Reductions in Toxicity, Mobility, and Volume through Treatment. Upon attainment of RAO 2, the plume is estimated to be reduced from current size by 87 percent.
- Cost. The separate assembly present value cost of Alternative III for AOPC 2 Priest Rapids-Roza 1 NEP is estimated at \$2,000,000. This cost does not include the associated cost of the basic actions, and it should be used to compare against other assemblies for this AOPC/aquifer. (This comparison is done in section 4.3.)

Additional Advantages and Disadvantages.

- Advantage. Exact knowledge of the source is not required for this treatment to achieve RAO 2.
- Disadvantage. While it does address RAO 2, implementation of this alternative may have low marginal benefit. Exposure-related controls (whole-house filters) are already established in this relatively limited area with few residences. The low TCE concentrations, while still greater than the PRAG, would mean that treatment would remove only a small amount of TCE mass.

Alternative III for AOPC 2 Roza 2

Additional Evaluation Criteria details.

- Short-Term Effectiveness. Time to accomplish RAO 2 is estimated to be 7 years. The time shown in the short-term effectiveness represents the time from system startup to the time that clean water flows past the farthest downgradient edge of the AOPC. Because this timeframe is estimated using general groundwater velocity, actual downgradient cleanup times may be longer than shown.

- Long-Term Effectiveness. Although the upgradient plume is not well defined, approximately 11 ac of contaminated groundwater would remain untreated within the footprint of this AOPC.
- Reductions in Toxicity, Mobility, and Volume through Treatment. Upon attainment of RAO 2, the plume will be reduced from current size by 47 percent. (This is based on an assumption that the area exceeding the PRAG occupies the same footprint as the AOPC 2 Priest Rapids-Roza 1 MP.)
- Cost. The separate assembly present value cost of Alternative III for AOPC 2 Roza 2 is estimated at \$2,100,000. This cost does not include the associated cost of the basic actions, and it should be used to compare against other assemblies for this AOPC/aquifer. (This comparison is done in section 4.3.)

Additional Advantages and Disadvantages

- Advantage. Exact knowledge of the source is not required for this treatment to be effective in achieving RAO 2.
- Disadvantage. Treating this plume may not make any major practical difference because the Basic Action components would address exposure, and the plume is already restricted to the nonresidential area according to current estimates. The relatively low dissolved concentrations may indicate a small source (or limited inputs from Priest Rapids-Roza 1), that could diminish without direct treatment if Priest Rapids-Roza 1 is treated.

4.2.3.4 *Alternative IV – Basic Action with In-Situ Treatment*

The actions included under the Basic Action component of this alternative are the same as those identified in section 4.2.3.2. Design details for the in-situ chemical treatment (ISCT) injection systems are based on a number of assumptions (see appendix F). As stated in chapter 3, for the purposes of the GWFS, nanoscale ZVI is selected as the ISCT reagent for FS-level design and costing for this alternative. Injection wells would be as close to the suspected source as possible (figure 4.2-2).

The calculation of the required ZVI is based on injection of sufficient reagent to react with TCE in order to reduce TCE in the treatment area to ethane and chloride ions. Oxygen “competes” with TCE for ZVI, and groundwater dissolved oxygen concentrations are considered high. An additional complication for any in-situ treatment is the unknown nature of the contaminant source. ISCT can be effective for treating dissolved-phase plumes when combined with source control, and ISCT can be effective for treating sources when those sources are sufficiently characterized. The foregoing does not describe the conditions at the Site. According to vendors, nanoscale ZVI has a treatment zone of approximately 50 ft from the point of reagent injection, which results in the well arrays shown in figure 4.2-3.

ISCT has a potential benefit of both dissolved plume treatment (which it shares with Alternative III) and potential source reduction (which Alternative III does not have). To gain the benefit of source reduction, identification and characterization of the source are deemed necessary prior to implementing ISCT for source reduction. Because a single set of injections would not likely achieve significant source reduction, the FS-level design specifies 30 years of

twice-annual ZVI injections. This key assumption leads to an expensive treatment, which may be an overestimate of costs if source characteristics were understood and properly scoped. The alternative includes remedial design, groundwater modeling, and bench-scale and pilot-scale studies.

Table 4.2-2 summarizes the evaluation for each alternative in general and important points are discussed below.

Discussions of AOPC/aquifer combinations follow in subsequent sections. It is generally assumed that injection of reagents into an area where residents are using the groundwater, or a municipal water supply withdrawal occurs, is unlikely to be selected as a treatment technology. Therefore, Alternative IV was not considered for AOPC 2 NEP Priest Rapids-Roza 1.

- Overall Protectiveness. Meets RAO 1, and is protective of human health during active remediation. No unacceptable short-term or cross-media impacts are anticipated. Basic Action is a critical component of this alternative because the treatment alone would not address immediate exposure to TCE in groundwater. Because hazardous substances remain onsite, 5-year reviews are required to assess effectiveness.
- Compliance with ARARS. May not meet the ARARs associated with RAO 3, because it is unlikely that each aquifer would likely be returned to concentrations below 5 µg/L in all areas. ARARs are met with respect to RAOs 1 and 2, but significant uncertainty remains regarding the achievement of RAO 3 (prevent or minimize further migration of contaminants from source materials to groundwater) since the alternative is not currently designed to treat subsurface TCE sources within the treatment area. The PRAG value will continue to be exceeded in an area within AOPCs. However, these areas may be defined and circumscribed by a compliance boundary. This action may require a Technical Infeasibility Waiver. This alternative is the only one that has the opportunity for source treatment, should a source be identified.
- Short-Term Effectiveness. Meets RAOs 1 and 2. Because this alternative includes a treatment technology that addresses plume extent, its timeframe for achievement of RAO 2 can be evaluated. The timeframes for remediation of the downgradient plumes to meet RAO 2 vary by AOPC were estimated using simple groundwater flow velocity calculations. The time shown in the short-term effectiveness represents the time from system startup to the time that clean water flows past the farthest downgradient edge of the AOPC. Because this timeframe is estimated using general groundwater velocity, actual downgradient cleanup times may be longer than shown.
 - AOPC 1 Priest Rapids-Roza 1 — 10 years.
 - AOPC 1 Roza 2 — 16 years.
 - AOPC 2 Priest Rapids-Roza 1 MP — 0 years (achieved close to time zero).
 - AOPC 2 Priest Rapids-Roza 1 NEP — not applicable.
 - AOPC 2 Roza 2 — 4 years.
- Long-Term Effectiveness and Permanence. Despite the uncertainty of Alternative IV in achieving RAO 3 (thereby leaving an unknown quantity of residual risk from the

unidentified source), this alternative provides the best identified opportunity for so doing. With the FS-level design, a 30-year timeframe (which is also that used for cost estimation) is assumed. Upon attaining RAO 2, residual risk from exposure to contaminated water would be limited to the area upgradient of the treatment, for so long as treatment is required. Injection of reagent would be required until the groundwater source is depleted, to achieve RAO 3. It is estimated that Alternative III would leave approximately 110 ac of groundwater contaminated above the PRAG in two aquifers. (This estimate compares to 690 ac prior to the remediation.) Were injections terminated prior to treating the entirety of the source, "rebound" of TCE concentrations from the remaining source material is anticipated.

The in-situ injection system is sized from existing data, which are limited to the dissolved-phase concentrations. Were source(s) to be encountered, the in-situ treatment may be capable of being adjusted to treat it. Practically speaking, whether source treatment may be attained depends upon source "architecture" (e.g., whether it is widely distributed in narrow and hard-to-penetrate fissures). Frequent reagent injections, one per year, were assumed in the cost estimate, for the entire 30-year economic estimation period. This **projection** may be an overestimate. Source treatment could reduce the residual risk to levels lower than dissolved-phase treatment and would provide the opportunity to end Basic Actions in the remediated area. It is not possible to project a timeframe for attainment of RAO 3 given the uncertainty described above.

- **Reductions in Toxicity, Mobility, and Volume through Treatment.** The treatment in Alternative IV addresses the widespread contaminated groundwater and reduces the risk posed by the contamination. The treatment destroys TCE in the aquifer through a chemical reaction resulting in nontoxic by-products. No additional treatments are needed and excess reagent is not harmful to human health or the environment. Additionally, all treatment activities are conducted onsite. This alternative alone has the potential to treat subsurface groundwater TCE sources, if they may be located.

As with Alternative III, the treatment in Alternative IV occurs near the head of the groundwater plume and relies on physical attenuation processes to reduce TCE concentrations downgradient. The treatment will reduce AOPC 1's area by 99 percent and AOPC 2's area by 79 percent. Residual risks are managed by incorporation of Alternative II (Basic Action).

The reactions within the treatment of Alternative IV are not reversible. However, were the treatment to cease, concentrations could return to concentrations in excess of the PRAG.

- **Implementability.** Injection wells are not a difficult technology per se, but the injection of the reactive slurry into the subsurface is more difficult in fractured bedrock than in gravelly or sandy aquifers. Technical difficulties of in-situ treatment may include injection of the treatment agent into the most concentrated areas of the treatment zone, and optimizing applications of reagent to account for dissolved oxygen.

Access to treatment areas would have to be acquired prior to implementation, and substantive requirements of permits would be needed. O&M costs may be less important

for the in-situ treatment alternative as opposed to the pump and treat alternative. However, remedial design may require more information to optimize the number of injections and effectiveness of the reagent.

Services and materials (including several types of injectable iron) for the in-situ treatment are generally available without additional storage capacities due to the onsite mixing just prior to use of the materials. Equipment and treatment specialists are readily available. This technology is scalable for the size and concentrations found at the Site but has been assumed to require bench and pilot tests.

- Cost. The estimated present value for Alternative IV if applied to four of the five treatment areas would approximate \$60,900,000. This cost includes the Basic Action cost (see Alternative II).

Advantages and Disadvantages

- Advantage. Alternative IV may be designed to treat a groundwater-based primary source, if one may be isolated.
- Disadvantage. The high costs based on the continual treatment of the dissolved-phase plume are due to the treatment typically being used in a few applications to either treat an isolated plume after the source has been controlled or to treat a delineated source.

Alternative IV – AOPC 1

AOPC 1 treatment is placed near to Site 20 because the subsurface source appears to be in that vicinity. However, it would be advantageous for additional characterization during the RD phase to better identify the subsurface source. The proposed treatment at AOPC 1 consists of a line of 13 wells (26 total for both aquifers) spread across 645 ft with a 50 ft wide treatment area based on current data. Table 4.2-2 includes design details. The installation of numerous injection wells would provide additional opportunities to locate a source. (Note: if a source or strong signals of a source were encountered during installation of the injection wells, then the source investigation and subsequent redesign would result in a cost change from the existing estimate.)

Access to a privately owned site is needed for further remedial design characterization and remedial action. Access for maintenance would be limited to a few days per injection phase for the duration of remedial action necessary to effectively treat the area. Although commerce would not likely be negatively impacted by ISCT outside of the brief injection phases, land-use restrictions may be necessary for the actual treatment area to protect the injection wellheads. Provided appropriate arrangements are made with the landowner, there are no known restrictions within the presumed treatment area to affect the feasibility of drilling and injection.

Alternative IV for AOPC 1 Priest Rapids-Roza 1

Additional Evaluation Criteria details.

- Short-Term Effectiveness. Time to accomplish RAO 2 is estimated to be 10 years. The time shown in the short-term effectiveness represents the time from system startup to the

time that clean water flows past the farthest downgradient edge of the AOPC. Because this timeframe is estimated using general groundwater velocity, actual downgradient cleanup times may be longer than shown.

- Long-Term Effectiveness. There is the potential to achieve RAO 3 at this location. If used as described, Alternative IV would leave 2.5 ac of contaminated groundwater will remain within the footprint of this AOPC.
- Reductions in Toxicity, Mobility, and Volume through Treatment. Upon attainment of RAO 2, the plume will be reduced from current size by 99 percent.
- Cost. The separate assembly present value cost of Alternative IV for AOPC 1 Priest Rapids-Roza 1 is estimated at \$6,300,000. This cost does not include the associated cost of the basic actions, and it should be used to compare against other assemblies for this AOPC/aquifer. (This comparison is done in section 4.3.)

Additional advantages and Disadvantages.

- Advantage. As there is an evident connection between this aquifer and Roza 2 and concentrations in the lower basalt aquifer are lower, cleanup in Priest Rapids-Roza 1 may be partially effective in starving the source of the lower contamination.
- Advantage. The opportunity to meet RAO 3 exists in AOPC 1 Priest Rapids-Roza 1.
- Disadvantage. Aquifer depth, low TCE concentrations, and inability to precisely place treatment reagent are disadvantages of this alternative.

Alternative IV for AOPC 1 Roza 2

- Short-Term Effectiveness. Time to accomplish RAO 2 is estimated to be 16 years. The time shown in the short-term effectiveness represents the time from system startup to the time that clean water flows past the farthest downgradient edge of the AOPC. Because this timeframe is estimated using general groundwater velocity, actual downgradient cleanup times may be longer than shown.
- Long-Term Effectiveness. There is the potential to achieve RAO 3 at this location. If used as described, Alternative IV would leave 2.5 ac of contaminated groundwater will remain within the footprint of this AOPC.
- Reductions in Toxicity, Mobility, and Volume through Treatment. Upon attainment of RAO 2, the plume will be reduced from current size by 99 percent (same areal projection as AOPC 1 Priest Rapids-Roza 1).
- Cost. The separate assembly present value cost of Alternative IV for treatment in AOPC 1 – Roza 2 is estimated at \$3,400,000. This cost does not include the associated cost of the basic actions, and it should be used to compare against other assemblies for this AOPC/aquifer. (This comparison is done in section 4.3.)

Additional Advantages and Disadvantages

- Advantage. The opportunity to meet RAO 3 exists in AOPC 1 Roza 2.

- Disadvantage. Aquifer depth, low TCE concentrations, and limited TCE characterization data are disadvantages of this alternative.

Alternative IV – AOPC 2

ISCT is believed to be more difficult to implement in AOPC 2 than in AOPC 1, due mainly to the large area requiring treatment. Also, logistical difficulties may occur in a part of the area due to timing and height restrictions affecting well drilling in the flight path of the airport. To optimize use of ISCT in AOPC 2 and achieve RAO 3, further source investigation is included in the cost estimate. Balancing these potential logistics issues, the placement of 72 wells in this area (36 in each aquifer) could result in the incidental discovery of a source or sources.

Alternative IV is not proposed for the treatment area in the NEP area due to the close proximity of residential well users using the water that would be treated and the low TCE mass treated by using this remedy at such relatively low concentrations.

Access to the Site would be needed for the characterization and remedial action phases, but such access for maintenance would require only a few days twice per year for the duration of remedial action. Commercial activities are not anticipated to be negatively impacted by ISCT because there is only a small real estate requirement for the wellheads, and no bulky aboveground structures as in Alternative III. Provided easements may be arranged with the landowner, there are no known restrictions within the presumed treatment area likely to prohibit drilling and injection, negatively impacted

Alternative IV for AOPC 2 Priest Rapids-Roza 1 MP only

Additional Evaluation Criteria details.

- Short-Term Effectiveness. Time to accomplish RAO 2 is practically 0 years due to the current plume project coinciding with commercial/industrial border. However, time to reduce plume to its smallest size (without source treatment) is estimated to be 4 years. The time shown in the short-term effectiveness represents the time from system startup to the time that clean water flows past the farthest downgradient edge of the AOPC. Because this timeframe is estimated using general groundwater velocity, actual downgradient cleanup times may be longer than shown.
- Long-Term Effectiveness. Approximately 110 ac of contaminated groundwater would remain untreated within the footprint of this AOPC.
- Reductions in Toxicity, Mobility, and Volume through Treatment. Upon attainment of RAO 2, the plume ($\text{TCE} \geq \text{PRAG}$) will be reduced from current size by 79 percent.
- Cost. The estimated separate assembly present value cost for Alternative IV treatment in AOPC 2 Priest Rapids-Roza 1 MP is \$29,000,000. This cost does not include the associated cost of the basic actions, and it should be used to compare against other assemblies for this AOPC/aquifer. (This comparison is done in section 4.3.)

Additional Advantages and Disadvantages.

- Disadvantage. As noted, there is a possibility that treatment of the upper aquifer may incidentally diminish TCE concentrations in this aquifer without direct treatment.
- Disadvantage. The projected number of wells to be installed in the treatment line provides an excellent opportunity to locate a source. However, due to the likelihood of numerous contributors to the plume, locating and treating a source would not guarantee the achievement of RAO 3.

Alternative IV for AOPC 2 Roza 2

- Short-Term Effectiveness. Time to accomplish RAO 2 is estimated to be 4 years. The time shown in the short-term effectiveness represents the time from system startup to the time that clean water flows past the farthest downgradient edge of the AOPC. Because this timeframe is estimated using general groundwater velocity, actual downgradient cleanup times may be longer than shown.
- Long-Term Effectiveness. Approximately 110 ac of contaminated groundwater would remain untreated within the footprint of this AOPC.
- Reductions in Toxicity, Mobility, and Volume through Treatment. Upon attainment of RAO 2, the plume will be reduced from current size by 79 percent (same projection as AOPC 2 Priest Rapids-Roza 1 MP).
- Cost. The estimated separate assembly present value cost of Alternative IV treatment in AOPC 2 Roza 2 is \$14,000,000. This cost does not include the associated cost of the basic actions, and it should be used to compare against other assemblies for this AOPC/aquifer. (This comparison is done in section 4.3.)

Additional Advantages and Disadvantages.

- Disadvantage. Aquifer depth, low TCE concentrations, and the difficulties and uncertainties regarding the in-situ treatment are disadvantages of this alternative.
- Disadvantage. There is a possibility that treatment of the upper aquifer may have the same effect on this aquifer as source treatment; thereby, eliminating the need for remedial action in this treatment area.

4.3 COMPARATIVE ANALYSIS OF ALTERNATIVES

In this section, remedial options are assessed relative to one another for the two threshold criteria and five balancing criteria. The two modifying factors, State acceptance and community acceptance, are not considered in this evaluation, but will be evaluated after publication of the Proposed Plan as part of the development of the ROD. The purpose of this comparison is to identify and discuss the relative advantages or disadvantages of each alternative to aid in the decision-making process.

Alternatives are scored on a pass/fail basis for the two threshold criteria (protection of human health and environment and compliance with ARARs). The alternatives passing the threshold

The comparison below is semiquantitative in order to present a rating of the alternatives described above for each alternative and AOPC/aquifer. Equal rating was given if it was not possible to differentiate performance for the given criteria. For the balancing criteria, rankings from one to four are assigned, based on their expected performance relative to the other alternatives:

- The following text table shows how the various alternatives were scored and ranked. The following sections and table 4.2-2 describe the comparison and the basis for the ranking.

4.3.1 Overall Protectiveness of Human Health and the Environment

• Alternative I – No Action	
○ Site wide	FAIL
• Alternative II – Basic Action Only	
○ Site wide	FAIL
○ AOPC/aquifer-basis	PASS on a provisional basis

- Alternative III – Basic Action with Groundwater Extraction and Ex-Situ Treatment
 - AOPC 1 Priest Rapids-Roza 1 PASS
 - AOPC 1 Roza 2 PASS
 - AOPC 2 Priest Rapids-Roza 1 MP PASS
 - AOPC 2 Priest Rapids-Roza 1 NEP PASS
 - AOPC 2 Roza 2 PASS
- Alternative IV – Basic Action with In-Situ Groundwater Treatment
 - AOPC 1 Priest Rapids-Roza 1 PASS
 - AOPC 1 Roza 2 PASS
 - AOPC 2 Priest Rapids-Roza 1 MP PASS
 - AOPC 2 Priest Rapids-Roza 1 NEP N/A
 - AOPC 2 Roza 2 PASS

4.3.2 Compliance with ARARs

- Alternative I – No Action
 - Site wide FAIL
- Alternative II – Basic Action Only
 - Site wide FAIL – but provides protectiveness
 - AOPC/aquifer-basis FAIL – but provides protectiveness
- Alternative III – Basic Action with Groundwater Extraction and Ex-Situ Treatment
 - AOPC 1 Priest Rapids-Roza 1 FAIL – but provides protectiveness, plume reduction
 - AOPC 1 Roza 2 FAIL – but provides protectiveness, plume reduction
 - AOPC 2 Priest Rapids-Roza 1 MP FAIL – but provides protectiveness, plume reduction
 - AOPC 2 Priest Rapids-Roza 1 NEP FAIL – but provides protectiveness, plume reduction
 - AOPC 2 Roza 2 FAIL – but provides protectiveness, plume reduction
- Alternative IV – Basic Action with In-Situ Groundwater Treatment
 - AOPC 1 Priest Rapids-Roza 1 FAIL – but provides protectiveness, plume reduction
 - AOPC 1 Roza 2 FAIL – but provides protectiveness, plume reduction
 - AOPC 2 Priest Rapids-Roza 1 MP FAIL – but provides protectiveness, plume reduction
 - AOPC 2 Priest Rapids-Roza 1 NEP N/A
 - AOPC 2 Roza 2 FAIL – but provides protectiveness, plume reduction

4.3.3 Short-Term Effectiveness

In general, the remaining application areas for the alternatives are not significantly different in their short-term effectiveness, as indicated by the timeframes to meet RAO 2, with the exception of Basic Action only applied to a specific aquifer.

Upon attainment of RAO 2, the water upgradient from the line or zone of treatment wells will not have been treated. As noted in section 2.1, to meet RAO 2, the reduced plumes should be entirely within areas within which existing controls are protective of human health. These are areas where no residential habitation occurs, such as areas zoned commercial industrial or Port owned. However, should a plume's hotspot occur outside of an area that may be confidently said to be nonresidential, then attainment of RAO 2 would require the reduction of plume to within the treatment/capture zone of the treatment or extraction well(s).

Reduction of TCE concentration in an overlying aquifer may also reduce the TCE contribution of that aquifer to lower aquifers. This assumption holds true provided the mode of TCE migration is dissolved phase and that there is no secondary source within the next aquifer.

4.3.4 Long-Term Effectiveness and Permanence

Overall, Alternatives III and IV are similar with respect to long-term effectiveness and permanence due to the variations in reduction in acreage of untreated groundwater. In AOPC 1 Priest Rapids-Roza 1, Alternative IV receives a more favorable ranking because of the relatively limited area of the suspected source, which improves the capability of the technology to address source reduction and thereby provide a permanent remedy.

4.3.5 Reduction of Toxicity, Mobility, and Volume through Treatment

The key comparison for this category is percent reduction in areal extent of contaminated groundwater. The differences between the two action alternatives are due to well placement locations. The extraction wells for Alternative III are placed further downgradient of the hotspots, resulting in a smaller reduction of contaminated area than in Alternative IV, which places treatment injection wells near the suspected source. Note that the analysis did not consider Alternative IV for the AOPC Priest Rapids-Roza 1 NEP as it would entail injection of reagents near current domestic water supplies, and could result in taste and color in a drinking water source. Because of this, Alternative III results in greater plume reduction in AOPC 2.

4.3.6 Implementability

Implementability is generally favorable across alternatives with the exception of Alternative IV. Alternative IV uses the in-situ technology in an unusual way. Typically, ISCT is applied to a dissolved-phase plume after the source is controlled, or to a source that has been adequately characterized. Additionally, logistics of working in the airport flight path for the length of time needed to install the large number of wells in AOPC 2 might be problematic.

4.3.7 Cost

Alternative I is the least costly alternative; Alternative II is 100 times Alternative I; Alternative II is 2.3 times Alternative II (which it includes); Alternative IV is about 4 times as expensive as III. The substantial difference between Alternatives III (\$18,900,000) and IV (\$60,900,000) is largely due to the assumed need for a long period of injections (estimated at 30 years).

4.4 SUMMARIZED RESULTS OF THE DETAILED ANALYSIS OF ALTERNATIVES

The detailed analysis of alternatives resulted in the ranking of Basic Action as the most favorable alternative for application at all AOPCs (Site wide). For the AOPCs individually, alternatives ranked as most favorable include in-situ groundwater treatment for AOPC 1 Priest Rapids-Roza 1, ex-situ groundwater treatment for AOPC 2 Priest Rapids-Roza 1 MP, and no immediate action with contingency groundwater treatment for the remaining AOPCs. The following subsections provide the summary of alternative rankings by groundwater treatment area.

4.4.1 AOPC 1 Priest Rapids-Roza 1

The overall scores for the alternatives applied to AOPC 1 Priest Rapids-Roza 1 are the following:

- | | |
|----------------------------------|----------------------------|
| • Alternative I | Failed – no protectiveness |
| • Alternative II | 8 |
| • Alternative II | |
| AOPC 1 Priest Rapids-Roza 1 only | 8 |
| • Alternative III | 14 (contingent action) |
| ❖ Alternative IV | 16 (most favorable) |

For AOPC 1 Priest Rapids-Roza 1, Alternative IV was determined to be the most favorable alternative because of possible treatment of the TCE source. If a source were to be found, its removal would speed the overall site cleanup. As conceived for this GWFS, 13 injection points would be installed near the prospective source. These would improve the chances of finding a source; they could also be used for sampling and monitoring. In contrast, Alternative III consists of one extraction well, farther away from the prospective source. Nanoscale ZVI injected quantities may be adjusted to match the in-water concentrations. Since it appears that the contamination is continuing downwards into lower aquifers, treatment of Priest Rapids-Roza 1 would reduce TCE migration to Roza 2.

These benefits assume source identification, because investigation up to this point has been unable to identify a secondary source. The additional cost above Alternative III to apply the technology at this AOPC/aquifer is \$6,300,000, based on current information. There would be value to gathering further pre-remedial design information to identify the source, and estimated cost for a remedial-design-phase pilot study to refine placement is \$330,000. If a source were not found, then Alternative III would be more cost effective, and will be reconsidered as a contingent action.

4.4.2 AOPC 1 Roza 2

The overall scores for the Alternatives applied to AOPC 1 Roza 2 are the following:

- | | |
|--------------------|----------------------------|
| • Alternative I | Failed – no protectiveness |
| • Alternative II | 8 |
| ❖ Alternative II | |
| AOPC 1 Roza 2 only | 8 (most favorable) |

- Alternative III 14 (contingent action)
- Alternative IV 13

For this treatment area, Alternative II in conjunction with active treatment in AOPC 1 Priest Rapids-Roza 1 was found to be most favorable of the alternatives; and contingent use of extraction and ex-situ treatment if determined necessary.

- Even with active treatment, the estimated time to reach RAO 2 is 14 to 16 years. This is the longest estimated period to reach plume control, and is due to the slow flow rate in Roza 2. Alternative II is suggested until sufficient information is available to determine whether treatment of the upper aquifer is effectively reducing the Roza 2 concentrations of TCE.
- Due to the limited extent of data on this aquifer, it is important to have more information in order to best select an active treatment. Such information may be obtained from the long-term monitoring program described within the Basic Action or additional investigations. Once more data are assessed, active treatment (through Alternative III treatment) is a contingent action. However, should evidence suggest a localized NAPL source in Roza 2, then Alternative IV could be considered based on cost-benefit analysis.
- The additional cost of Alternative IV over Alternative III is \$1,400,000; 70 percent more than Alternative III.

4.4.3 AOPC 2 Priest Rapids-Roza 1 MP

The overall scores for the Alternatives applied to AOPC 2 Priest Rapids-Roza 1 MP area are the following:

- Alternative I Failed – no protectiveness
- Alternative II 8
- Alternative II AOPC 2 Priest Rapids-Roza 1 MP only 8
- ❖ Alternative III 16 (most favorable)
- Alternative IV 12

The plume already meets RAO 2, since its leading edge is currently close to the urban commercial/industrial zone, although there is uncertainty with the exact leading edge. Just outside the urban commercial/industrial boundary, the residential community is served by the CML water supply. Implementing treatment could assure that plume remains fully within Port-controlled land; this provides assured control to prevent exposures. Treating a source to accomplish RAO 3 is unlikely in this area with either Alternative III or IV. However, vertical migration of TCE to lower aquifers is of concern; thus, Alternative III was determined to be the most favorable alternative.

Cost is a major factor between Alternatives III and IV, because the marginal benefit is small and the cost differential is large. Alternative IV is \$26,000,000 more costly than III, which costs \$3,200,000. This differential is due to the numerous, dispersed wells to be placed with Alternative IV in the vicinity of three large landfills. More wells placed would somewhat

increase the likelihood of hitting a source. However, finding and treating a single source among many would not provide a significant benefit towards source reduction for the entire AOPC.

4.4.4 AOPC 2 Priest Rapids-Roza 1 NEP

The overall scores for the alternatives applied to AOPC 2 Priest Rapids-Roza 1 NEP area are the following:

- | | |
|--------------------------------------|----------------------------|
| • Alternative I | Failed – no protectiveness |
| • Alternative II | 8 |
| ❖ Alternative II | |
| AOPC 2 Priest Rapids-Roza 1 NEP only | 8 (most favorable) |
| • Alternative III | 14 (contingent action) |
| • Alternative IV | (not considered; see text) |

For this treatment area, Alternative II – specifically, an alternative clean-water supply – was found to be the most favorable alternative in the detailed analysis of alternatives for AOPC 2 Priest Rapids-Roza 1 NEP. Alternative III for AOPC 2 Priest Rapids-Roza 1 NE is a contingent action, depending upon monitoring. Also, a data gap in Roza 2 was noted, and filling that gap is part of the recommended Alternative II.

This treatment area is zoned residential. Implementing a treatment system would not reduce the plume in this treatment zone to an urban commercial/industrial or Port-owned area; hence, RAO 2 would not be achievable. Monitoring of the plume and the alternate water supply would ensure protectiveness. The source in AOPC 2 Priest Rapids-Roza 1 NEP is unknown, but observed concentrations at well 99-BW15 appear to fluctuate back and forth between 10 and 14 µg/L, and have been stable for at least the past 6 years. The main benefit of installing a treatment system would be to reduce these already low concentrations to below 5 µg/L.

Alternative II is also listed as most favorable because of the potentially impacted public is known, and can be protected by alternative water supply and/or point-of-use filters. Costs to provide impacted residents with a new water supply are much less than a treatment system. The \$7,900,000 cost for Basic Action covers actions for the entire site, and would include the costs in this treatment zone. To additionally treat this area, it would require an additional \$2,000,000.

4.4.5 AOPC 2 Roza 2

The scores for the alternatives applied to AOPC 2 Roza 2 are the following:

- | | |
|---------------------------------------|----------------------------|
| • Alternative I | Failed – no protectiveness |
| • Alternative II | 8 |
| ❖ Alternative II – AOPC 2 Roza 2 only | 8 (most favorable) |
| • Alternative III | 14 (contingent action) |
| • Alternative IV | 11 |

For this treatment area, Alternative II was determined to be the most favorable alternative in conjunction with active treatment in AOPC 2 Priest Rapids-Roza 1 MP; and treatment would

likely be determined necessary. The estimated time for Roza 2 to reach RAO 2 is 7 years. Because of the limited extent of TCE data for this aquifer, it is important to obtain more concentration trend and hydrogeologic information in order to determine the scope of any active treatment. Later, with more information it may be possible to be more confident in treatment selection. In the first few years' monitoring (part of Alternative II), it will be possible to ascertain whether cleanup in Priest Rapids-Roza 1 is reducing TCE in, or otherwise impacting, Roza 2. If TCE concentrations are not reducing over time and are widespread, then Alternative III would be the preferred treatment option. If evidence appears that there is a localized source in Roza 2, or if the source is determined to be controlled in Roza 1, then Alternative IV could be considered. The additional cost of Assembly 4 over Assembly 3 is \$12,000,000, six times the cost of Assembly 3 for this treatment area. Selection of Alternative IV over Alternative III is unlikely due to the cost differential.

4.4.6 Cost Summary

Total project FS-level costs of the alternatives and assemblies found to be most favorable are shown below.

Treatment Area	Primary	Present Value Cost	Contingent	Present Value Cost
All AOPCs	Basic Action	\$7,900,000	N/A	N/A
AOPC 1 Priest Rapids- Roza 1	Assembly 4 cost for Alternative IV – Basic Action with In-Situ Treatment due to possibility of treating source; cost includes pilot study to see if possible to determine prospective source area	\$6,300,000	Switch to Assembly 3 Costs for Assembly 3 are captured within costs for Assembly 4	N/A
AOPC 1 Roza 2	No Assembly cost for Alternative II – Basic Action only Action contingent upon effective treatment of the upper aquifer to reduce the Roza 2 concentrations of TCE	N/A	Add Assembly 3 if AOPC 1 Priest Rapids-Roza 1 treatment is shown not to have reduced Roza 2 concentrations	\$2,000,000
AOPC 2 Priest Rapids- Roza 1 MP	Assembly 4 for Alternative III – Basic Action with Ex-Situ Treatment Designed for bringing the plume to within airport boundaries	\$3,200,000	Add additional pumping capacity downgradient to reduce impacted area; cost range is assumed to be accounted for within main design cost	N/A
AOPC 2 Priest Rapids- Roza 1 NEP	Alternative II – Basic Action only Implementing a treatment system would not reduce to the plume in this treatment zone to an urban commercial/ industrial or Port-owned area; hence RAO 2 would not be achievable. Monitoring of the plume and the alternate water supply would ensure protectiveness	N/A	Add Assembly 3	\$2,000,000
AOPC 2 Roza 2	No Assembly cost for Alternative II – Basic Action only Action contingent upon effective treatment of the upper aquifer to reduce the Roza 2 concentrations of TCE	N/A	Add Assembly 3 if AOPC 2 Priest Rapids-Roza 1 treatment is shown not to have reduced Roza 2 concentrations	\$2,100,000
Total Range of Present Value Costs		\$17,400,000	with contingencies	\$23,500,000

CHAPTER 5
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GROUNDWATER FEASIBILITY STUDY

TABLES

Moses Lake Wellfield Contamination Superfund Site

Moses Lake, Washington

April 2007



**US Army Corps
of Engineers®**
Seattle District

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Table 1.3-1 City of Moses Lake Drinking Water Well Construction Data by Well Depth

Well Number	Ground Elevation (mean sea level)	Well Depth (feet)	Aquifer
29	1,154	134	Unconsolidated (U)*
12	1,199	568	Wanapum (W)
10	1,058	692	W
31	1,056	696	W & U
21	1,188	712	W
24	1,167	725	W
28	1,180	750	W
23	1,167	**791	W
11	1,148	**805	W
3	1,070	909	W & Grande Ronde (GR)
7	1,065	950	GR
4	1,079	1,000	GR & W
14	1,085	1,027	GR
8	1,092	1,045	GR & W
9	1,108	1,100	GR
17	1,210	1,240	GR

* City plan states “unconsolidated,” but well log indicates unconsolidated and Wanapum (source: Marcia Knadle, correspondence, June 29, 2005).

** Grande Ronde has been sealed off in these wells.

Table Source: City of Moses Lake, 2000.

Table 1.4-1 Groundwater Flow Velocities

	K (ft/d)	i	n_e	v_h (ft/d)	v_v (ft/d)
Hanford Formation	20,000	0.005	0.25	400	
Ringold Formation	0.2	0.005	0.1	0.01	
Priest Rapids-Roza 1	70	0.004	0.15	2	
Roza 2	6	0.01	0.06	1	
Roza 1 to Roza 2	0.4	0.1	unk		unk

Key:

i - gradient

K - 1,000

ft/d - feet per day

n_e - effective porosity

v_h - horizontal velocity

v_v - vertical velocity

unk - unknown

Table 1.5-1 Chemicals of Concern for Future Impact to Groundwater, by Potential Source Area

	Inorganic Compounds									Organic Compounds					
	Antimony	Arsenic	Cadmium	Chromium	Lead	Manganese	Mercury	Nickel	Zinc	PAHs	Oilmdx TPH	DieselmDx	GRO-Gx	PCB	TCE
PSA															
PSA 2 – Big Bend Community College Hangar	x	x						x	x						
PSA 7 – Rock Landfill															
PSA 8 – Randolph Road Base Dump			x						x	x					
PSA 11 – Fire Training Area/Burn Pit B										x	x				
PSA 12 – Motor Pool Drain			x						x	x	x	x			
PSA 15 – 8-Place Hangar Ditch		x						x	x						
PSA 17 – 3-Place Hangar		x	x	x				x	x						
PSA 18 – Paint Hangar			x	x			x	x	x					x	
PSA 19 – LOX Plant						x		x	x	x					x
PSA 19b – LOX Disposal Site															
PSA 20 – South Base Dump			x	x	x			x	x						
PSA 21 – Larson WWTP															
PSA 22 – Paint Hangar Leach Pit			x	x				x	x						
PSA 27 – TEL 27											x				
PSA 28 – TEL 28											x				
PSA 29 – Low-Level Radioactive Medical Waste Disposal											x				
PSA 31 – 19th Avenue Base Dump			x	x				x	x						
PSA 33 – Dump at the End of Runway 32												x			
PSA 35 – Stained Soil Area			x	x				x	x		x	x	x		

Key:

DieselmDx - diesel range petroleum hydrocarbons
GroGx - gasoline range petroleum hydrocarbons
LOX - liquid oxygen
Oilmdx, TPH - oil range petroleum hydrocarbons
PAHs - polyaromatic hydrocarbons
PCB - polychlorinated biphenyls

PSA - potential source area

TCE - trichloroethene (note that this appears unlikely from the NEI results)

TEL - tetraethyl lead

WWTP - wastewater treatment plant

Table 1.5-2 Data used for Priest Rapids-Roza 1 Plume Distribution Map

Well	Northing	Easting	TCE (µg/L)	Date	Aquifer	AOPC
00-BW01	679483	2302080	<0.5	30-Oct-02	Roza 1	None
00-BW02	676693	2297085	0.25	29-Oct-02	Priest Rapids	AOPC 2
00-BW03	677715	2297833	<0.5	29-Oct-02	Priest Rapids	AOPC 2
00-BW04	680301	2299075	<0.5	30-Oct-02	Priest Rapids	None
00-BW05	681405	2299972	<0.5	30-Oct-02	Priest Rapids	None
00-BW06	679185	2288983	<0.5	28-Oct-02	Roza 1	AOPC 3
00-BW07	680141	2298256	<0.5	30-Oct-02	Priest Rapids	None
00-BW08	680177	2294584	<0.5	28-Oct-02	Priest Rapids	None
00-BW09	681888	2298237	<0.5	28-Oct-02	Priest Rapids	None
00-BW10	663992	2296915	<0.5	31-Oct-02	Roza 1	AOPC 1
00-BW11	678760	2294189	<0.5	1-Nov-02	Priest Rapids	AOPC 3
00-BW12	678744	2297443	24	22-Sep-04	Priest Rapids	AOPC 2
00-BW13	670557	2298368	<0.5	31-Oct-02	Priest Rapids	AOPC 1
00-BW14	679943	2301538	<0.5	13-Jan-03	Priest Rapids	None
00-BW15	674879	2298780	1.4	31-Oct-02	Priest Rapids	AOPC 2
00-BW16	668534	2294033	<0.5	1-Nov-02	Priest Rapids	AOPC 2
01-BW01	681816	2299623	<0.5	29-Oct-02	Priest Rapids	None
02-BW01	666419	2296560	18.2	20-Sep-04	Roza 1	AOPC 1
02-BW02 ^a	676774	2299817	0.27	27-Feb-03	Roza 1	AOPC 2
04-BW01	681874	2299688	<1	26-Jan-05	Roza 1	None
04-BW04	677872	2290925	2.47	28-Jan-05	Roza 1	AOPC 3
04-BW05	675636	2291611	6.06	27-Jan-05	Roza 1	AOPC 3
04-BW06	675147	2294659	19.8	2-Feb-05	Roza 1	AOPC 2
04-BW07	669985	2295473	<1	1-Feb-05	Roza 1	AOPC 2
04-BW09	670378	2297964	69.2	2-Feb-05	Priest Rapids	AOPC 1
04-CW05	669805	2297687	88 ^d	29-Aug-04	Priest Rapids	AOPC 1
91-BW01	692677	2288122	<0.5	24-Jan-01	Roza 1	None
91-BW02	680390	2294703	<0.5	19-Jan-01	Roza 1	None
91-BW03	675789	2295692	41.4	10-Aug-04	Roza 1	AOPC 2
91-BW04	672583	2296918	0.41	31-Oct-02	Roza 1	AOPC 2
92-BW01	676084	2297060	18.7	10-Aug-04	Roza 1	AOPC 2
92-BW02	675558	2297209	2.9	31-Oct-02	Roza 1	AOPC 2
99-BW01	675825	2295796	39.7	10-Aug-04	Roza 1	AOPC 2
99-BW04	692233	2303899	<0.5	16-Mar-00	Roza 1	None
99-BW05	690448	2294736	<0.5	25-Jan-01	Roza 1	None
99-BW06	676842	2307379	<0.5	16-Mar-00	Roza 1	None
99-BW08	663427	2307174	<0.5	16-Mar-00	Roza 1	None
99-BW09	665058	2300403	<0.5	1-Feb-01	Roza 1	None
99-BW10	666436	2296528	17.1	20-Sep-04	Priest Rapids	AOPC 1
99-BW11	665818	2292555	<0.5	14-Mar-00	Priest Rapids	None
99-BW12	673708	2293832	2.1 ^b	30-Oct-02	Priest Rapids	AOPC 2
99-BW13	671432	2296205	<0.5	22-Jan-01	Priest Rapids	AOPC 2

Table 1.5-2 Data used for Priest Rapids-Roza 1 Plume Distribution Map (cont.)

Well	Northing	Easting	TCE (µg/L)	Date	Aquifer	AOPC
99-BW14	671394	2300236	<0.5	18-Jan-01	Priest Rapids	None
99-BW15	676777	2299770	12	21-Sep-04	Priest Rapids	AOPC 2
99-BW16	678758	2291833	<2.3	10-Aug-04	Roza 1	AOPC 3
99-BW17	690419	2294778	<0.5	20-Mar-00	Roza 1	None
99-BW18	668701	2297649	19.3	22-Sep-04	Priest Rapids	AOPC 1
WP-03	668885	2292259	0.65J	21-Sep-04	Priest Rapids-Roza 1	AOPC 2
WP-07	679730	2303668	<2.1	3-Aug-04	Priest Rapids-Roza 1	None
WP-09	666269	2293066	0.2	18-Nov-02	Priest Rapids-Roza 1	AOPC 1
WP-11	669128	2291818	<0.5	22-Jun-00	Priest Rapids-Roza 1	AOPC 2
WP-14	676885	2300327	7.81	19-Apr-05	Roza 1	AOPC 2
WP-15E	666243	2297156	12.4	1-Oct-02	Priest Rapids-Roza 1	AOPC 1
WP-15W	665834	2295764	1.1 ^c	4-Aug-04	Priest Rapids-Roza 1 & Roza 2	AOPC 1
WP-16	662519	2294557	<0.5	23-Jun-00	Roza 1	AOPC 1
WP-17	662749	2294312	<0.5	23-Jun-00	Roza 1	AOPC 1
WP-20S	665372	2293889	<0.5	1999	Priest Rapids-Roza 1	AOPC 1
WP-21	663316	2297247	<0.5	1999	Priest Rapids-Roza 1	AOPC 1
WP-24	667485	2302698	<0.5	1999	Roza 1	None
WP-26	658091	2292156	<0.5	30-Aug-00	Roza 1 & Roza 2	None
WP-27	665166	2298019	<0.5	1999	Priest Rapids- Alluvium	AOPC 1
WP-32	666436	2299932	<0.5	1999	Roza 1	AOPC 2
WP-33	668970	2290866	<0.5	31-Jan-01	Roza 1	AOPC 2
WP-34	662519	2291741	<0.5	14-Nov-02	Priest Rapids-Roza 1	AOPC 1
WP-38	665094	2300490	<0.5	1999	Roza 1	None
WP-41	662050	2300974	<0.5	1999	Roza 1	None
WP-46	662083	2295053	<0.5	1999	Roza 1 & Roza 2	AOPC 1
WP-49	663244	2291765	<0.5	15-Nov-02	Roza 1	AOPC 1
WP-60	663271	2292960	<0.5	19-Nov-02	Priest Rapids-Roza 1	AOPC 1
WP-64	662876	2294947	<0.5	1999	Roza 1	AOPC 1
WP-65	670192	2291012	<0.5	1999	Roza 1	AOPC 2
WP-68	668620	2292007	<0.5	1999	Priest Rapids-Roza 1	AOPC 2
WP-69	668879	2291800	<0.5	1999	Priest Rapids	AOPC 2
WP-70	669345	2291513	1.4J	4-Aug-04	Roza 1	AOPC 2
WP-71A	668184	2291997	<0.5	1999	Roza 1	AOPC 2
WP-71B	668177	2292247	1.4	21-Sep-04	Roza 1 & Roza 2	AOPC 2
WP-73	666712	2290345	<0.5	1999	Roza 1	AOPC 2
WP-77	666177	2295150	2 ^c	29-Jul-99	Priest Rapids-Roza 1 & Roza 2	AOPC 1
WP-82	676859	2301136	<0.5	19-Nov-02	Roza 1 & Roza 2	AOPC 2
WP-83	676790	2299547	1.61	21-Sep-04	Priest Rapids-Roza 1	AOPC 2
WP-86	676222	2293947	4.37	3-Aug-04	Roza 1 & Roza 2	AOPC 1

Table 1.5-2 Data used for Priest Rapids-Roza 1 Plume Distribution Map (cont.)

Well	Northing	Easting	TCE (µg/L)	Date	Aquifer	AOPC
WP-101	654426	2279341	<2.1	3-Aug-04	Roza 1	None
WP-105	669179	2291867	<1	20-Sep-04	Priest Rapids	AOPC 2
WP-107	677703	2293067	<2.1	3-Aug-04	Roza 1	AOPC 3
WP-108	681752	2289117	0.2J	3-Aug-04	Roza 1	None
WP-109	669773	2286803	<1	21-Sep-04	Roza 1	None
WP-110	666363	2284548	<1	21-Sep-04	Roza 1	None

Notes:

TCE data listed are most recent available for wells or borings that have drilling logs (and, therefore, known or inferred aquifer assignment). Because not all data are recent, plume distributions derived from them are considered approximations.

^a TCE stratified in aquifer; contours are based on 99-BW15.

^b May not be representative of entire aquifer because of unusual Priest Rapids characteristics at this location.

^c Possibly biased low because of Roza 2 dilution.

^d Result may be biased low due to inability to completely purge water added during drilling.

Key:

AOPC – area of potential concern

TCE – trichloroethene

µg/L – micrograms per liter

Table 1.5-3 TCE Mass and Volume by AOPC

		Aquifer			TCE		
		Areal extent	Thickness	Porosity	Concentration	Mass	Volume
		sq ft	ft	%	mg/L	kg	L
AOPC 1	Priest Rapids-Roza 1	26,000,000	45	15	0.011	56	38
	Roza 2		25	6	0.011	12	9
					AOPC 1 Total	68	47
AOPC 2	Priest Rapids-Roza 1	52,000,000	45	15	0.007	70	48
	Roza 2		25	6	0.007	16	11
					AOPC 2 Total	86	59
AOPC 3	Priest Rapids-Roza 1	10,000,000	35	15	0.0025	3.7	2.5
	Roza 2		25	6	0.0005	0.2	0.1
					AOPC 3 Total	4	3
					TOTAL	158	108

Key:

AOPC – area of potential concern

TCE – trichloroethene

kg – kilograms

mg/L – milligrams per liter

sq ft – square feet

Note: Areal extent is assumed to be equivalent for all aquifers within an AOPC. Concentrations, mass, and volume refer to dissolved-phase only. TCE concentrations are weighted averages based on TCE distribution shown in figure 1.5-3.

Table 1.5-4 TCE Data from Roza 2

Well	Northing	Easting	TCE (µg/L)	Sample Date	Depth (ft)	Associated with AOPC^a
04CW01	677873.43	2290981.88	2.89	1/28/2005	302	Preliminary AOPC 3
04CW02	675661.54	2291596.79	2.33	1/27/2005	305	Preliminary AOPC 3
04CW03	675789.34	2295796.39	22.4	1/26/2005	267	AOPC 2
04CW03	675789.34	2295796.39	22.5	1/26/2005	275	AOPC 2
04CW03	675789.34	2295796.39	22.5	1/26/2005	281	AOPC 2
04CW04	670004.82	2295466.10	1.01	2/1/2005	308	AOPC 1/2
04CW05	670004.82	2295466.10	17.7	1/25/2005	263	AOPC 1
04CW05	670004.82	2295466.10	17.3	1/25/2005	270	AOPC 1
04CW05	669805.28	2297686.91	29.6	1/25/2005	277	AOPC 1
04CW07	666670.36	2296554.50	3.81	2/1/2005	283-293/303-309 ^b	AOPC 1
04CW07	666670.36	2296554.50	4	2/1/2005	306	AOPC 1
04CW08	663467.73	2296159.77	2.44	2/2/2005	305	AOPC 1

Notes:

^a "Associated" means used to define the AOPC.

^b 04-CW07 has two well screens in the Roza 2 aquifer. (See section 2.1 of appendix A.)

Key:

AOPC – area of potential concern

TCE – trichloroethene

ft – feet

µg/L – micrograms per liter

**Table 1.6-1 Groundwater Risk Model, Priest Rapids and Roza 1 Members Combined
(RI Table 6.57)**

Member <i>Cluster Identification/Well</i>	Groundwater Exposure Point Concentration (mg/L)	Future Resident Risk		Future Commercial/ Industrial Worker		Hypothetical Unrestricted Drinking Water Scenario	
		ILCR	HI	ILCR	HI	ILCR	HI
Hanford/Ringold (HR)							
<i>Well - 00A-W11</i> Trichloroethene	0.0051	na ^a	na ^a	5.0E-07	0.025	1.1E-06	0.090
<i>Well – 91-AW14</i> Bromodichloromethane	0.00061	na ^a	na ^a	5.2E-07	0.00030	1.1E-06	0.0013
Dibromochloromethane	0.00037						
<i>Well – 91-AW15</i> 1,2,4-Trimethylbenzene	0.0035	na ^a	na ^a	na ^b	0.0065	na ^b	0.025
1,3,5-Trimethylbenzne	0.0069						
Priest Rapids-Roza 1 Combined (PR-R1)							
<i>PR-R1 Cluster #1a – 91-BW03, 92-BW01, 99-BW01</i> Trichloroethene	0.046	1.0E-05	0.81	4.5E-06	0.22	1.0E-05	0.81
<i>PR-R1 Cluster #1b – 99-BW15, 02-BW02</i> Trichloroethene	0.012	2.6E-06	18	1.2E-06	3.8	2.6E-06	18
Acetone	19						
<i>PR-R1 Cluster #2 – 02-BW01, 99- BW18, 99-BW10</i> Trichloroethene	0.025	5.4E-06	0.44	2.5E-06	0.12	5.4E-06	0.44
<i>Well – 00-BW02</i> Manganese	0.122	na ^a	na ^a	na ^b	0.017	na ^b	0.078
<i>Well – 00-BW11</i> Benzene	0.00043	na ^a	na ^a	2.0E-07	0.0031	4.2E-07	0.013
<i>Well – 00-BW12</i> Trichloroethene	0.028	na ^a	na ^a	2.8E-06	0.16	6.1E-06	0.60
Manganese	0.16						
<i>Well – 00-BW13</i> Manganese	0.18	na ^a	na ^a	na ^b	0.025	na ^b	0.12

**Table 1.6-1 Groundwater Risk Model, Priest Rapids and Roza 1 Members Combined
(RI Table 6.57) (cont.)**

Member <i>Cluster Identification/Well</i>	Groundwater Exposure Point Concentration (mg/L)	Future Resident Risk		Future Commercial/ Industrial Worker		Hypothetical Unrestricted Drinking Water Scenario	
		ILCR	HI	ILCR	HI	ILCR	HI
Well – 00-BW18		na ^a	na ^a	na ^b	0.00038	na ^b	0.0017
Methyl tertiary butyl ether (MTBE)	0.016						
Well – 92-BW02		na ^a	na ^a	na ^b	0.00094	na ^b	0.0043
MTBE	0.040						
Well – 99-BW16		na ^a	na ^a	8.6E-06	0.298	6.9E-07	0.035
Trichloroethene	0.0054						
DW Cluster #1 - WP-15E, WP-15W		6.1E-06 ^c	0.50 ^c	2.8E-06 ^c	0.14 ^c	6.1E-06 ^c	0.50 ^c
Trichloroethene	0.028						
Well – WP-13E		1.0E-06	0.0011	4.9E-07	0.00025	1.0E-06	0.0011
Bromodichloromethane	0.00038						
Dibromochloromethane	0.00052						
Well – WP-14		1.7E-06	0.14	7.7E-07	0.038	1.7E-06	0.14
Trichloroethene	0.0078						

Note:

^a Future residential risk estimates were not calculated for this well cluster or monitoring well because it is located within a non-residential land use area, as per the Grant County Master Plan.

^b No carcinogenic chemicals of potential concern were identified for this monitoring well.

^c The indicated risks for WP-15W (Skyline Well #1) are based on RI data collected prior to replacement of this well. Current and anticipated future risks for well WP-15W are lower than estimates shown, as the well is no longer used.

Key:

Bold text indicates exceedance of MTCA target risk level

mg/L – milligrams per liter

HI – hazard index

HR – Hanford/Ringold

ILCR – incremental lifetime cancer risk

MTBE – methyl tertiary butyl ether

MTCA – Model Toxics Control Act

PR-RI – Priest Rapids-Roza 1 Combined

RI – remedial investigation

Table 2.2-1 Potential Groundwater Chemical Specific Laws And Regulations

Regulation	Citation	Description	Evaluation
Federal Requirements			
Safe Drinking Water Act (SDWA)	42 U.S.C. 300f et seq. as amended 40 CFR 141 references standards	This act establishes primary regulations for the protection of the public health and secondary regulations relating to the taste, odor, and appearance of drinking water.	Maximum contaminant levels are promulgated and applicable requirements with the exception of water systems serving 4 or fewer connections (see also Washington Administrative Code [WAC] 246-290). This set a chemical-specific ARAR for TCE of 5 µg/L. Maximum contaminant level goal (MCLG) and Secondary MCL are both non-promulgated values under this Act. (See also CERCLA and WAC 173-200, below.)
State Requirements			
Washington State Requirements to Protect the Health of Consumers using Public Drinking Water Supplies	Washington Administrative Code (WAC) 246-290 and 291	WAC 246-291-100, Ground Water Source Approval and Protection, states: "Existing sources shall conform to the primary water quality standards established in this chapter. Proposed sources shall conform to the primary and secondary water quality standards established in this chapter...."	Refers to Secondary MCL for manganese of 0.05 mg/L. This is neither ARAR nor TBC. (See also Water Quality Standards for Ground Water in the State of Washington.

Table 2.2-1 Potential Groundwater Chemical Specific Laws And Regulations (cont.)

Regulation	Citation	Description	Evaluation
Water Quality Standards for Ground Waters in the State of Washington	WAC 173-200	The regulation specifies means to protect groundwater by determining methods to prevent intrusion of contaminants from affecting groundwater. WAC 173-200-040 states, "for the primary and secondary contaminants and radionuclides listed in Table 1, the criteria shall be the most stringent concentration of the following and those listed in Table 1: (i) Maximum contaminant level goals; (ii) Maximum contaminant levels; and (iii) State maximum contaminant levels published in chapter 248-54 WAC....."	The Washington groundwater quality standards are not remediation standards. As per WAC 173-200-010(3), the groundwater standards do not apply to cleanup actions approved by Washington Department of Ecology under MTCA, RCW chapter 70.105D (State of Washington Water Pollution Control Act), or those approved by the USEPA under CERCLA, 42 U.S.C. 9601 et seq. (Groundwater cleanup standards for such sites are developed under MTCA, WAC 173-340-720, q.v..)
Water Quality Standards for Surface Waters in the State of Washington	WAC 173-201A	Adopts and promulgates the Ambient Water Quality Criteria, and the National Toxics Rule (40 CFR 131.36).	For TCE, the criterion for organisms-only consumption for protection of human health is 81 µg/L, and there are no standards for manganese or acetone. Because the groundwater discharge does not affect surface water, these values are neither ARAR nor TBC.
Washington Model Toxics Control Act (MTCA)	Chapter 70.105D RCW WAC 173-340	All cleanup actions approved by the Department of Ecology under the Model Toxics Control Act or EPA under CERCLA shall include ground water cleanup standards developed under WAC 173-340-720.	MTCA Method A value for TCE of 5 µg/L is neither applicable (because the cleanup is occurring under CERCLA) nor relevant and appropriate (because it is not more restrictive than the primary Federal MCL). For acetone, a to be considered Method B value was derived: 7.2 µg/L. Methods B and C are not substantive in nature, and hence are not relevant and appropriate.

Table 2.2-1 Potential Groundwater Chemical Specific Laws and Regulations (cont.)

Key:

ARAR – applicable or relevant and appropriate requirements
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
CFR – Code of Federal Regulations
EPA, USEPA – U.S. Environmental Protection Agency
MCL – maximum contaminant level
MCLG – maximum contaminant level goal
MTCA – Washington Model Toxics Control Act
RCW – Revised Code of Washington
SDWA – Safe Drinking Water Act
TBC – to be considered
TCE – trichloroethene
U.S.C. – U.S. Code
WAC – Washington Administrative Code
µg/L – micrograms per liter

Table 2.2-2 Potential Groundwater Action-Specific Laws and Regulations

Regulation	Citation	Description	Evaluation
Federal Requirements			
Resource Conservation and Recovery Act (RCRA)	42 U.S.C. 6901 et seq. 40 CFR 260, 261, 262, 263, and 268	<p>Establishes management standards for hazardous waste, including characterization, generator, transportation and disposal requirements. RCRA and CERCLA §121(c)(3)(B) require that any materials that exceed the maximum concentration for Toxicity Characteristic (40 CFR 261.24, table 1) and are disposed offsite shall be carried out only at hazardous waste disposal facilities that are in compliance with Subtitle C of RCRA. CERCLA §121(d)(3) further states that transfer of hazardous substances shall be made only to facilities that are operating in compliance with §§3004 and 3005 of the Solid Waste Disposal Act (or, where applicable, in compliance with the Toxic Substances Control Act or other applicable Federal law) and all applicable State requirements.)</p> <p>RCRA section 3020 addresses re-injection of contaminated ground water into underground sources of drinking water which are part of CERCLA response or RCRA corrective actions.</p>	<p>The D040 Characteristic Waste category fits concentrations of leachable TCE above 500 µg/L if it occurs in waste materials. (Note: this concentration has not been seen any onsite media to date, but could occur if TCE were concentrated on sorbent treatment media.) It would be an action-specific applicable requirement if conditions are encountered.</p> <p>Section 3020 is neither an ARAR nor TBC, but must be complied with should the circumstance arise during remediation. (The intention of the cleanup is to treat extracted water so that it may be considered clean. The definition of clean derives from WAC 173-200, above).</p>

Table 2.2-2 Potential Groundwater Action-Specific Laws and Regulations (cont.)

Regulation	Citation	Description	Evaluation
Hazardous Materials Transportation Act	49 U.S.C. 1801 et seq. 49 CFR 170-180	Transportation of wastes and materials which are hazardous materials (e.g., RCRA hazardous wastes) must be packaged, placarded, and manifested in accordance with the Act.	Should hazardous materials be encountered or created through treatment (e.g., by concentration through sorption of TCE onto a medium), the substantive portions (characterization) would need to be complied with whilst onsite. However, for offsite transportation, this may not be considered an ARAR by definition, because it is off site.
The Safe Drinking Water Act (SDWA)	42 U.S.C. 300f et seq. as amended 40 CFR 141	Community water systems must monitor to determine compliance with the MCLs specified in Sec. 141.62. 40 CFR 141.23 inorganic chemical sampling and analytical requirements.	For Group A and B systems, monitoring is required. (Groundwater regulations are administered by the Department of Health with cooperation from Grant County.) Only should a new water supply be identified as a response action that met A and B size requirements would this be an ARAR. (No current alternatives specify such an action.)
State Requirements			
Clean Air Act Controls for New Sources of Toxic Air Pollutants	WAC 173-460	This regulation addresses air quality issues associated with emissions of toxic air pollutants. TCE is a State Class A toxic. WAC 173-460-030(b)(iii)(B) states sites subject to WAC 173-340, the Model Toxics Control Act, are also subject to WAC 173-460.	The Best Available Control Technology for Toxics (T-BACT) for TCE emissions could be an action-specific relevant and appropriate requirement should the remedy include emissions of TCE to ambient air.
Washington Dangerous Waste Regulations	WAC 173-303	The regulation contains a series of rules relating to the generation, handling, storage and disposal of dangerous waste.	If wastes are managed onsite, WAC 173-303 substantive requirements pertaining to dangerous waste generation, handling, storage, and disposal would be applicable. For any non-exempt dangerous wastes transported off the site during cleanup, the regulation would be not be applicable, although legal compliance offsite would be required.

Table 2.2-2 Potential Groundwater Action-Specific Laws and Regulations (cont.)

Regulation	Citation	Description	Evaluation
Ground water Source Approval and Protection	WAC 246-291-100	System owner shall ensure that proposed sources shall conform to the primary and secondary water quality standards established in this chapter.	This is an administrative requirement and may be TBC if a public water system were to be established as part of remedy. To be considered for establishing water wells for residences up to 4 individuals on the same farm. Washington Department of Health, and local Health District monitor public water systems, coordinates and/or approves new water systems, and provides for collection of water samples.

Key:

ARAR – applicable or relevant and appropriate requirements
 CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
 CFR – Code of Federal Regulations
 EPA, USEPA – U.S. Environmental Protection Agency
 MCL – maximum contaminant level
 MCLG – maximum contaminant level goal
 MTCA – Washington Model Toxics Control Act
 RCRA – Resource Conservation and Recovery Act
 RCW – Revised Code of Washington
 SDWA – Safe Drinking Water Act
 T-BACT – The Best Available Control Technology for Toxics
 TBC – to be considered
 TCE – trichloroethene
 U.S.C. – U.S. Code
 WAC – Washington Administrative Code
 µg/L – micrograms per liter

Table 2.2-3 Potential Groundwater Location-specific Laws and Regulations

Regulation	Citation	Description	Evaluation
Federal Requirements			
None identified			
State and Local Requirements			
None identified			

Key:

CFR – Code of Federal Regulations

U.S.C. – U.S. Code

**Table 2.2-4 Potential Preliminary Remediation Goals for Groundwater at
Moses Lake Wellfield Contamination Superfund Site**

The principal basis for value is shown in boldface.

Compound	Primary MCL	Secondary MCL ^a	MCL Goal	MTCA Method A	MTCA Method B	Potential ARAR or TBC?
<i>Organic Compounds, mg/L</i>						
Acetone					7.2	TBC Only if Cleanup Required
TCE	0.005		0			MCL is Applicable

Key:

ARAR – applicable or relevant and appropriate requirements

MCL – maximum contaminant level

MTCA – Washington Model Toxics Control Act

TBC – to be considered

TCE – trichloroethene

mg/L – milligrams per liter

Table 2.5-1 Technologies and Process Options Considered for Soil and Groundwater

General Response Action	Technology	Process Option
No Action	No Action	No Action
Institutional Controls	Governmental	Zoning controls Local permits Police power ordinances Groundwater use restrictions Condemnation of property
	Proprietary	Easements Covenants Equitable Servitude Reversionary Interest State Use Restrictions Conversation Easements
	Enforcement Tools	Administrative orders Consent decrees
	Informational Devices	Deed notices State registries of hazardous wastes sites Advisories Educational programs
Other Controls	Physical Barriers (surface)	Fencing
	Alternate Water Supply	City water Other water purveyor connections New well Provided water
	Individual Well Treatment	Activated Carbon Adsorption Low-Profile Air Stripping Ultra Violet Oxidation
	Long-Term Monitoring	Long-term monitoring
	Natural Attenuation with Monitoring	Natural attenuation with monitoring
Containment	Surface Barrier	Surface Capping

Table 2.5-1 Technologies and Process Options Considered for Soil and Groundwater (cont.)

General Response Action	Technology	Process Option
No Action	No Action	No Action
Ex-Situ Treatment	Physical Barrier	Deep soil mixing wall
		Sheet pile wall
	Groundwater Extraction and Collection	Slurry wall
		Oil filling of bedrock fissures
		Pumping for Hydraulic Control
	Excavation, Retrieval, and Offsite Disposal (soil)	Draw-down pumping
		Excavation, Retrieval, and Offsite Disposal
	Physical/ Chemical	Chemical Extraction
		Chemical Reduction/ Oxidation
		Dehalogenation
		Soil Washing
	Biological Treatments	Adsorption/Absorption
		Advanced Oxidation Processes
		Air Stripping
		Deep Well Injection
	Thermal Treatments	Separation
		Sprinkler Irrigation
		Biopiles
		Composting
		Landfarming
		Slurry Phase Biological Treatment
		Bioreactors
		Constructed Wetlands
		Incineration
		Pyrolysis
		Thermal Desorption

Table 2.5-1 Technologies and Process Options Considered for Soil and Groundwater (cont.)

General Response Action	Technology	Process Option
No Action	No Action	No Action
In-Situ Treatment	Physical/ Chemical	Chemical Oxidation Electrokinetic Separation Fracturing Soil Flushing <i>Soil Vapor Extraction</i> Air Sparging Bioslurping Dual Phase Extraction <i>In-Well Air Stripping</i> Passive/Reactive Treatment Walls Zero Valent Iron
	Biological Treatment	Bioremediation Phytoremediation Aerobic Biodegradation Anaerobic Biodegradation
	Thermal Treatments	Thermally-Enhanced Soil Vapor Extraction Steam Injection and Extraction Electrical Resistant Heating
Treatment Technology Components Considered (Not a GRA)	Air Emissions/ Off-Gas Treatments	High Energy Destruction Membrane Separation Oxidation Vapor Phase Carbon Adsorption
	Fluid Delivery Systems	Direct-Push Injection Wells Vertical Wells Horizontal Wells
	Process Option Enhancements	Circulating Wells Hydrofracturing

Table 2.5-2 Screening of Technologies and Process Options for Soil

Process Option	Description(s)	Retained	Rationale/ Application
No Action			
No Action	No Action	Yes	Retained for evaluation as per CERCLA guidance to provide baseline to other alternatives.
Institutional Controls			
Governmental Institutional Controls***	Controls using the regulatory authority of a governmental entity to impose restrictions on citizens or property under its jurisdiction. Usually, state or local governments have the jurisdiction.	No	This control will not prevent continuing release from a source to groundwater.
Proprietary Institutional Controls	Tools based on private property law used to restrict or affect the use of the property.	No	This control will not prevent continuing release from a source to groundwater
Enforcement Tools***	Enforcement authority is used to either (1) prohibit a party from using land in certain ways or from carrying out certain activities at a specified property, or (2) require a settling party to put in place some other form of control.	No	This control will not prevent continuing release from a source to groundwater
Informational Devices***	Tools, which often rely on property record systems, used to provide public information about risks from contamination. May effectively discourage inappropriate land users from acquiring the property.	No	This control will not prevent continuing release from a source to groundwater
Other Controls			
Physical Barriers			
Fencing and Surface Capping***	Containment treatments, such as fencing and surface capping, are often performed to prevent, or significantly reduce, the migration of contaminants in soils or groundwater. Containment is necessary whenever contaminated materials are to be buried or left in place at a site. In general, containment is performed when extensive subsurface contamination at a site precludes excavation and removal of wastes because of potential hazards, unrealistic cost, or lack of adequate treatment technologies. Containment treatments offer quick installation times and are typically a low to moderate cost treatment group. Unlike ex-situ treatment groups, containment does not require excavation of soils that lead to increased costs from engineering design of equipment, possible permitting, and material handling. However, these treatments require periodical inspections for settlement, ponding of liquids, erosion, and naturally occurring invasion by deep-rooted vegetation. Additionally, groundwater monitoring wells, associated with the treatments, need to be periodically sampled and maintained. Even with these long-term requirements containment treatments usually are considerably more economical than excavation and removal of the wastes.	No	<p>This control will not prevent continuing release from a source to groundwater</p> <p>This technology will not prevent continuing release from a source to groundwater. None of the landfill cap uses apply to source removal directly, but may be reintroduced as part of a treatment train.</p>

Table 2.5-2 Screening of Technologies and Process Options for Soilcont.)

Process Option	Description(s)	Retained	Rationale/ Application
Containment			
Excavation, Retrieval, and Offsite Disposal***	Contaminated material is removed and transported to permitted offsite treatment and/or disposal facilities. Some pretreatment of the contaminated media usually is required in order to meet land disposal restrictions.	No	Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to excavate the source. However, if during the course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.
	Confined disposal facilities (CDFs) are engineered structure enclosed by dikes and designed to retain dredged materials. A CDF may have a large cell for material disposal, and adjoining cells for retention and decantation of turbid, supernatant water. A variety of linings have been used to prevent seepage through the dike walls. The most effective are clay or bentonite-cement slurries, but sand, soil, and sediment linings have also been used. Operation and maintenance duration lasts as long as the life of the facility.		
	Location and design are two important CDF considerations. Terms to consider in the location of a CDF are the physical aspects (size, proximity to a navigable waterway), the design/construction (geology/hydrology), and the environmental (current use of the area, environmental value, and environmental effects). The primary goal of a CDF design is minimization of contaminant loss. Caps are the most effective way to minimize contaminant loss from CDFs, but selection of proper liner material is also an important control on CDFs. Finally, CDFs require continuous monitoring to ensure structural integrity.		
Ex-Situ Treatments (Dissolved and/or Source-level Contaminant Migration Prevention – assumes excavation)			
Physical/ Chemical Treatments			
Chemical Extraction***	Chemical extraction does not destroy wastes but is a means of separating hazardous contaminants from soils, sludges, and sediments, thereby reducing the volume of the hazardous waste that must be treated. The technology uses an extracting chemical and differs from soil washing, which generally uses water or water with wash-improving additives. Commercial-scale units are in operation. They vary in regard to the chemical employed, type of equipment used, and mode of operation.	No	Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to excavate the source. However, if during the course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.
	Physical separation steps are often used before chemical extraction to grade the soil into coarse and fine fractions, with the assumption that the fines contain most of the contamination. Physical separation can also enhance the kinetics of extraction by separating out particulate heavy metals, if these are present in the soil.		
Chemical Reduction/ Oxidation***	Reduction/oxidation (Redox) reactions chemically convert hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, and/or	No	Not retained for further evaluation because a source has not been

Table 2.5-2 Screening of Technologies and Process Options for Soil (cont.)

Process Option	Description(s)	Retained	Rationale/ Application
	inert. Redox reactions involve the transfer of electrons from one compound to another. Specifically, one reactant is oxidized (loses electrons) and one is reduced (gains electrons). The oxidizing agents most commonly used for treatment of hazardous contaminants are ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide. Chemical reduction/oxidation is a short- to medium-term technology.		discovered nor delineated. It is therefore impossible to excavate the source. However, if during the course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.
Dehalogenation***	Contaminated soil is screened, processed with a crusher and pug mill, and mixed with reagents. The mixture is heated in a reactor. The dehalogenation process is achieved by the replacement either of the halogen molecules or the decomposition and partial volatilization of the contaminants.	No	Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to excavate the source. However, if during the course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.
Soil Washing***	<p>Ex situ soil separation processes (often referred to as "soil washing"), mostly based on mineral processing techniques, are widely used in Northern Europe and America for the treatment of contaminated soil. Soil washing is a water-based process for scrubbing soils ex situ to remove contaminants. The process removes contaminants from soils in one of the following two ways:</p> <ul style="list-style-type: none"> • By dissolving or suspending them in the wash solution (which can be sustained by chemical manipulation of pH for a period of time); or • By concentrating them into a smaller volume of soil through particle size separation, gravity separation, and attrition scrubbing (similar to those techniques used in sand and gravel operations). <p>Soil washing systems incorporating most of the removal techniques offer the greatest promise for application to soils contaminated with a wide variety of heavy metal, radionuclides, and organic contaminants. Commercialization of the process, however, is not yet extensive.</p> <p>The concept of reducing soil contamination through the use of particle size separation is based on the finding that most organic and inorganic contaminants tend to bind, either chemically or physically, to clay, silt, and organic soil particles. The silt and clay, in turn, are attached to sand and gravel particles by physical processes, primarily compaction and adhesion. Washing processes that separate the</p>	No	Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to excavate the source. However, if during the course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.

Table 2.5-2 Screening of Technologies and Process Options for Soil (cont.)

Process Option	Description(s)	Retained	Rationale/ Application
	<p>fine (small) clay and silt particles from the coarser sand and gravel soil particles effectively separate and concentrate the contaminants into a smaller volume of soil that can be further treated or disposed of. Gravity separation is effective for removing high or low specific gravity particles such as heavy metal-containing compounds (lead, radium oxide, etc.). Attrition scrubbing removes adherent contaminant films from coarser particles. However, attrition washing can increase the fines in soils processed. The clean, larger fraction can be returned to the site for continued use.</p> <p>Complex mixture of contaminants in the soil (such as a mixture of metals, nonvolatile organics, and SVOCs) and heterogeneous contaminant compositions throughout the soil mixture make it difficult to formulate a single suitable washing solution that will consistently and reliably remove all of the different types of contaminants. For these cases, sequential washing, using different wash formulations and/or different soil to wash fluid ratios, may be required.</p> <p>Soil washing is generally considered a media transfer technology. The contaminated water generated from soil washing is treated with the technology(s) suitable for the contaminants. The duration of soil washing is typically short to medium term.</p>		
Biological Treatment			
Biopiles***	<p>Biopile treatment is a full-scale technology in which excavated soils are mixed with soil amendments and placed on a treatment area that includes leachate collection systems and some form of aeration. It is used to reduce concentrations of petroleum constituents in excavated soils through the use of biodegradation. Moisture, heat, nutrients, oxygen, and pH can be controlled to enhance biodegradation.</p> <p>The treatment area will generally be covered or contained with an impermeable liner to minimize the risk of contaminants leaching into uncontaminated soil. The drainage itself may be treated in a bioreactor before recycling. Vendors have developed proprietary nutrient and additive formulations and methods for incorporating the formulation into the soil to stimulate biodegradation. The formulations are usually modified for site-specific conditions.</p> <p>Soil piles and cells commonly have an air distribution system buried under the soil</p>	No	Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to excavate the source. However, if during the course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.

Table 2.5-2 Screening of Technologies and Process Options for Soil (cont.)

Process Option	Description(s)	Retained	Rationale/ Application
	<p>to pass air through the soil either by vacuum or by positive pressure. The soil piles in this case can be up to 20 feet high (generally not recommended, 2-3 meters maximum). Soil piles may be covered with plastic to control runoff, evaporation, and volatilization and to promote solar heating. If there are VOCs in the soil that will volatilize into the air stream, the air leaving the soil may be treated to remove or destroy the VOCs before they are discharged to the atmosphere.</p> <p>Biopile is a short-term technology. Duration of operation and maintenance may last a few weeks to several months. Treatment alternatives include static processes such as: prepared treatment beds, biotreatment cells, soil piles, and composting.</p>		
Composting***	<p>Composting is a controlled biological process by which organic contaminants (e.g., PAHs) are converted by microorganisms (under aerobic and anaerobic conditions) to innocuous, stabilized byproducts. Typically, thermophilic conditions (54 to 65 °C) must be maintained to properly compost soil contaminated with hazardous organic contaminants. The increased temperatures result from heat produced by microorganisms during the degradation of the organic material in the waste. In most cases, this is achieved by the use of indigenous microorganisms. Soils are excavated and mixed with bulking agents and organic amendments, such as wood chips, animal, and vegetative wastes, to enhance the porosity of the mixture to be decomposed. Maximum degradation efficiency is achieved through maintaining oxygenation (e.g., daily windrow turning), irrigation as necessary, and closely monitoring moisture content, and temperature.</p> <p>There are three process designs used in composting: aerated static pile composting (compost is formed into piles and aerated with blowers or vacuum pumps), mechanically agitated in-vessel composting (compost is placed in a reactor vessel where it is mixed and aerated), and windrow composting (compost is placed in long piles known as windrows and periodically mixed with mobile equipment). Windrow composting is usually considered to be the most cost-effective composting alternative. Meanwhile, it may also have the highest fugitive emissions. If VOC or SVOC contaminants are present in soils, off-gas control may be required.</p>	No	Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to excavate the source. However, if during the course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.
Landfarming***	<p>Landfarming is a full-scale bioremediation technology, which usually incorporates liners and other methods to control leaching of contaminants, which requires excavation and placement of contaminated soils, sediments, or sludges.</p> <p>Contaminated media is applied into lined beds and periodically turned over or tilled</p>	No	Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to excavate the source. However, if during the

Table 2.5-2 Screening of Technologies and Process Options for Soil (cont.)

Process Option	Description(s)	Retained	Rationale/ Application
	<p>to aerate the waste.</p> <p>Soil conditions are often controlled to optimize the rate of contaminant degradation. Conditions normally controlled include: Moisture content (usually by irrigation or spraying). Aeration (by tilling the soil with a predetermined frequency, the soil is mixed and aerated). pH (buffered near neutral pH by adding crushed limestone or agricultural lime). Other amendments (e.g., Soil bulking agents, nutrients, etc.).</p> <p>Contaminated media is usually treated in lifts that are up to 18 inches thick. When the desired level of treatment is achieved, the lift is removed and a new lift is constructed. It may be desirable to only remove the top of the remediated lift, then construct the new lift by adding more contaminated media to the remaining material and mixing. This serves to inoculate the freshly added material with an actively degrading microbial culture, and can reduce treatment times.</p>		<p>course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.</p>
Slurry Phase Biological Treatment***	<p>Slurry phase biological treatment involves the controlled treatment of excavated soil in a bioreactor. The excavated soil is first processed to physically separate stones and rubble. The soil is then mixed with water to a predetermined concentration dependent upon the concentration of the contaminants, the rate of biodegradation, and the physical nature of the soils. Some processes pre-wash the soil to concentrate the contaminants. Clean sand may then be discharged, leaving only contaminated fines and washwater to biotreat. Typically, a slurry contains from 10 to 30% solids by weight.</p> <p>The solids are maintained in suspension in a reactor vessel and mixed with nutrients and oxygen. If necessary, an acid or alkali may be added to control pH. Microorganisms also may be added if a suitable population is not present. When biodegradation is complete, the soil slurry is dewatered. Dewatering devices that may be used include clarifiers, pressure filters, vacuum filters, sand drying beds, or centrifuges.</p> <p>Slurry-phase bioreactors may be classified as short- to medium-term technologies.</p>	No	<p>Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to excavate the source. However, if during the course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.</p>
Thermal Treatment			
Incineration***	<p>High temperatures, 870 to 1,200 °C (1,400 to 2,200 °F), are used to volatilize and combust (in the presence of oxygen) halogenated and other refractory organics in hazardous wastes. Often auxiliary fuels are employed to initiate and sustain combustion. The destruction and removal efficiency (DRE) for properly</p>	No	<p>Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to excavate the</p>

Table 2.5-2 Screening of Technologies and Process Options for Soil (cont.)

Process Option	Description(s)	Retained	Rationale/ Application
	operated incinerators exceeds the 99.99% requirement for hazardous waste and can be operated to meet the 99.9999% requirement for PCBs and dioxins. Off gases and combustion residuals generally require treatment.		source. However, if during the course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.
Pyrolysis***	<p>Pyrolysis is formally defined as chemical decomposition induced in organic materials by heat in the absence of oxygen. In practice, it is not possible to achieve a completely oxygen-free atmosphere; actual pyrolytic systems are operated with less than stoichiometric quantities of oxygen. Because some oxygen will be present in any pyrolytic system, nominal oxidation will occur. If volatile or semivolatile materials are present in the waste, thermal desorption will also occur.</p> <p>Pyrolysis transforms hazardous organic materials into gaseous components, small quantities of liquid, and a solid residue (coke) containing fixed carbon and ash. Pyrolysis of organic materials produces combustible gases, including carbon monoxide, hydrogen and methane, and other hydrocarbons. If the off-gases are cooled, liquids condense producing an oil/tar residue and contaminated water. Pyrolysis typically occurs under pressure and at operating temperatures above 430 °C (800 °F). The pyrolysis gases require further treatment. The off-gases may be treated in a secondary combustion chamber, flared, and partially condensed. Particulate removal equipment such as fabric filters or wet scrubbers are also required.</p>	No	Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to excavate the source. However, if during the course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.
Thermal Desorption***	Thermal desorption is a physical separation process and is not designed to destroy organics. Wastes are heated to volatilize water and organic contaminants. A carrier gas or vacuum system transports volatilized water and organics to the gas treatment system. The bed temperatures and residence times designed into these systems will volatilize selected contaminants but will typically not oxidize them. All thermal desorption systems require treatment of the off-gas to remove particulates and contaminants. Particulates are removed by conventional particulate removal equipment, such as wet scrubbers or fabric filters. Contaminants are removed through condensation followed by carbon adsorption, or they are destroyed in a secondary combustion chamber or a catalytic oxidizer. Most of these units are transportable.	No	Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to excavate the source. However, if during the course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.
In-Situ Treatment			

Table 2.5-2 Screening of Technologies and Process Options for Soil (cont.)

Process Option	Description(s)	Retained	Rationale/ Application
Physical/ Chemical Treatment			
Chemical Oxidation***	The chemical oxidants most commonly employed to date include peroxide, ozone, and permanganate. These oxidants have been able to cause the rapid and complete chemical destruction of many toxic organic chemicals; other organics are amenable to partial degradation as an aid to subsequent bioremediation. In general the oxidants have been capable of achieving high treatment efficiencies (e.g., > 90 percent) for unsaturated aliphatic (e.g., trichloroethene [TCE]) and aromatic compounds (e.g., benzene), with very fast reaction rates (90 percent destruction in minutes). Field applications have clearly affirmed that matching the oxidant and in situ delivery system to the chemicals of concern (COCs) and the subsurface, geologic conditions is the key to successful implementation and achieving performance goals.	No	Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to treat the source. However, if during the course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.
Electrokinetic Separation***	<p>The principle of electrokinetic remediation relies upon application of a low-intensity direct current through the soil between ceramic electrodes that are divided into a cathode array and an anode array. This mobilizes charged species, causing ions and water to move toward the electrodes. Metal ions, ammonium ions, and positively charged organic compounds move toward the cathode. Anions such as chloride, cyanide, fluoride, nitrate, and negatively charged organic compounds move toward the anode. The current creates an acid front at the anode and a base front at the cathode. This generation of acidic condition in situ may help to mobilize sorbed metal contaminants for transport to the collection system at the cathode.</p> <p>The two primary mechanisms transport contaminants through the soil towards one or the other electrodes: electromigration and electro-osmosis. In electromigration, charged particles are transported through the substrate. In contrast, electro-osmosis is the movement of a liquid containing ions relative to a stationary charged surface. Of the two, electromigration is the main mechanism for the process. The direction and rate of movement of an ionic species will depend on its charge, both in magnitude and polarity, as well as the magnitude of the electro-osmosis-induced flow velocity. Non-ionic species, both inorganic and organic, will also be transported along with the electro-osmosis induced water flow.</p>	No	Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to treat the source. However, if during the course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.
Fracturing (Enhancements)***	Fracturing is an enhancement technology designed to increase the efficiency of other in situ technologies in difficult soil conditions. The fracturing extends and enlarges existing fissures and introduces new fractures, primarily in the horizontal direction. When fracturing has been completed, the formation is then subjected to vapor extraction, either by applying a vacuum to all wells or by extracting from	No	Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to treat the source. However, if during the course of

Table 2.5-2 Screening of Technologies and Process Options for Soil (cont.)

Process Option	Description(s)	Retained	Rationale/ Application
	selected wells, while other wells are capped or used for passive air inlet or forced air injection. Technologies commonly used in soil fracturing include pneumatic fracturing (PF), blast-enhanced fracturing and Lasagna™ process.		additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.
Soil Flushing***	In situ soil flushing is the extraction of contaminants from the soil with water or other suitable aqueous solutions. Soil flushing is accomplished by passing the extraction fluid through in-place soils using an injection or infiltration process. Extraction fluids must be recovered from the underlying aquifer and, when possible, they are recycled.	No	Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to treat the source. However, if during the course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.
Soil Vapor Extraction***	<p>Soil vapor extraction (SVE) is an in situ unsaturated (vadose) zone soil remediation technology in which a vacuum is applied to the soil to induce the controlled flow of air and remove volatile and some semivolatile contaminants from the soil. The gas leaving the soil may be treated to recover or destroy the contaminants, depending on local and state air discharge regulations. Vertical extraction vents are typically used at depths of 1.5 meters (5 feet) or greater and have been successfully applied as deep as 91 meters (300 feet). Horizontal extraction vents (installed in trenches or horizontal borings) can be used as warranted by contaminant zone geometry, drill rig access, or other site-specific factors.</p> <p>For the soil surface, geomembrane covers are often placed over soil surface to prevent short circuiting and to increase the radius of influence of the wells. Groundwater depression pumps may be used to reduce ground water upwelling induced by the vacuum or to increase the depth of the vadose zone. Air injection is effective for facilitating extraction of deep contamination, contamination in low permeability soils, and contamination in the saturated zone (see Air Sparging in Table 2.5-3). The duration of operation and maintenance for in situ SVE is typically medium to long term.</p>	No	Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to treat the source. However, if during the course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.

Table 2.5-2 Screening of Technologies and Process Options for Soil cont.)

Process Option	Description(s)	Retained	Rationale/ Application
Thermal Treatment			
Thermally-Enhanced Soil Vapor Extraction***	Thermally enhanced SVE is a full-scale technology that uses electrical resistance/electromagnetic/fiber optic/radio frequency heating or hot-air/steam injection to increase the volatilization rate of semi-volatiles and facilitate extraction. The process is otherwise similar to standard SVE, but requires heat resistant extraction wells. Thermally enhanced SVE is normally a short- to medium-term technology.	No	Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to treat the source. However, if during the course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.
Biological Treatment			
Enhanced Bioremediation***	Enhanced bioremediation is a process in which indigenous or inoculated micro-organisms (e.g., fungi, bacteria, and other microbes) degrade (metabolize) organic contaminants found in soil and/or groundwater, converting them to innocuous end products. Nutrients, oxygen, or other amendments may be used to enhance bioremediation and contaminant desorption from subsurface materials.	No	Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to treat the source. However, if during the course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.
Phytoremediation***	Phytoremediation is a process that uses plants to remove, transfer, stabilize, and destroy contaminants in soil and sediment. The mechanisms of phytoremediation include enhanced rhizosphere biodegradation, phyto-extraction (also called phyto-accumulation), phyto-degradation, and phyto-stabilization.	No	Not retained for further evaluation because a source has not been discovered nor delineated. It is therefore impossible to treat the source. However, if during the course of additional investigations at the site, a vadose zone source is discovered, this technology may be reconsidered.

*** Federal Remediation Technology Roundtable, 2005.

Key:

°C – degrees Celsius

°F – degrees Fahrenheit

CDF – confined disposal facilities

CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act

COC – chemical of concern

DRE – destruction and removal efficiency

PAH – polyaromatic hydrocarbons

PCB – polychlorinated biphenyls

PF – pneumatic fracturing

pH – potential hydrogen

Redox – reduction/oxidation

SVE – soil vapor extraction

SVOCs – semi-volatile organic compound

TCE – trichloroethene

VOC – volatile organic compound

Table 2.5-3 Screening of Technologies and Process Options for Groundwater

Process Option	Description(s)	Retained	Rationale/ Application
No Action			
No Action	No Action.	Yes – PR-R1 Yes – Roza 2	Retained as per CERCLA guidance to provide baseline to other alternatives.
Institutional Controls			
Governmental Controls*			
Zoning controls	Controls using the regulatory authority of a governmental entity to impose restrictions on citizens or property under its jurisdiction. Usually, state or local governments have the jurisdiction. These controls do not require the “parcel-to-parcel” proprietary controls. State or local governments actively manage these controls over the remedy-need lifetime.	Yes – PR-R1 Yes – Roza 2	Retained in general. Controls likely to be used include: access restrictions near airport.
Local permits			
Police power ordinances			
Groundwater use restrictions			
Condemnation of property			
Proprietary Controls*			
Easements	Tools based on private property law used to restrict or affect the use of the property.	Yes – PR-R1 Yes – Roza 2	Retained in general; exact controls need to be defined.
Covenants			
Equitable Servitude			
Reversionary Interest			
State Use Restrictions			
Conservation Easements			
Enforcement Tools*			
Administrative orders	Enforcement authority is used to either (1) prohibit a party from using land in certain ways or from carrying out certain activities at a specified property, or (2) require a settling party to put in place some other form of control.	Yes – PR-R1 Yes – Roza 2	Retained in general; exact controls need to be defined.
Consent decrees			
Informational Devices*			
Deed notices	Tools, which often rely on property record systems, used to provide public information about risks from contamination. May effectively discourage inappropriate land users from acquiring the property.	Yes – PR-R1 Yes – Roza 2	Retained in general; exact controls need to be defined.
State registries of hazardous waste sites			
Advisories			
Educational Programs			

Table 2.5-3 Screening of Technologies and Process Options for Groundwater (cont.)

Process Option	Description(s)	Retained	Rationale/ Application
Other Controls			
Alternate Water Supply			
City of Moses Lake	New connection.	Yes – PR-R1 Yes – Roza 2	Retained for evaluation.
Other water purveyor	New connection.		
New well	Installation of replacement well.		
Provided Water	Provide potable water.		
Individual Well Treatment			
Low-Profile Air Stripping	Engineering controls employed to treat extracted groundwater just prior to use.	Yes – PR-R1 Yes – Roza 2	Retained for evaluation.
Activated Carbon Adsorption			
UV Oxidation			
Surface barriers in Area of Potential Concern			
Fencing	Passive technologies designed to prevent groundwater-obtaining activities at the surface above the highest areas of contaminated groundwater.	Yes – PR-R1 Yes – Roza 2	Retained for evaluation. This process option is not likely to be a stand-alone action but used in conjunction with ICs.
Long-Term Monitoring			
Long-Term Monitoring	<p>All selected remedies are likely to include some type of monitoring. Monitoring options may consist of monitoring well networks and/or point-of-use monitoring. Monitoring wells are a standard technique used to establish presence of contaminants in groundwater (through collection and laboratory analysis of samples) and to ensure protectiveness of remedies. While construction, sampling, and analysis costs are low, effectiveness as a monitoring tool is only as good as the understanding of subsurface migration of contaminants. Furthermore, monitoring wells are not satisfactory as a stand-alone remedy, in that they are not intended to reduce or remove contaminants from groundwater.</p> <p>Point-of-use monitoring consists of taking groundwater samples from public water supply wells or residential wells and analyzing for chemicals of concern. Sampling and analysis are widely applied in the environmental industry, and associated costs are low. As with monitoring wells, point-of-use monitoring is effective at limiting exposure to contaminants but does nothing to remove groundwater contaminants.</p>	Yes – PR-R1 Yes – Roza 2	Retained for evaluation as part of any treatment as method of understanding possible exposure and possible contaminant plume changes.

Table 2.5-3 Screening of Technologies and Process Options for Groundwater (cont.)

Process Option	Description(s)	Retained	Rationale/ Application
Natural Attenuation with Monitoring			
Natural Attenuation w/ Monitoring**	<p>Natural subsurface processes such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials are allowed to reduce contaminant concentrations to acceptable levels. Natural attenuation is not a "technology" per se, and there is significant debate among technical experts about its use at hazardous waste sites. Consideration of this option usually requires modeling and evaluation of contaminant degradation rates and pathways and predicting contaminant concentration at down gradient receptor points, especially when plume is still expanding/migrating. The primary objective of site modeling is to demonstrate that natural processes of contaminant degradation will reduce contaminant concentrations below regulatory standards or risk-based levels before potential exposure pathways are completed. In addition, long term monitoring must be conducted throughout the process to confirm that degradation is proceeding at rates consistent with meeting cleanup objectives. Natural attenuation is considered in the Superfund program on a case-by-case basis, and guidance on its use is still evolving. Compared with other remediation technologies, natural attenuation has the following advantages:</p> <ul style="list-style-type: none"> • Less generation or transfer of remediation wastes; • Less intrusive as few surface structures are required; • May be applied to all or part of a given site, depending on site conditions and cleanup objectives; • Natural attenuation may be used in conjunction with, or as a follow-up to, other (active) remedial measures; and • Overall cost will likely be lower than active remediation. 	<p>Yes – PR-R1 Yes – Roza 2</p>	<p>Retained for evaluation for the possibility of reducing further migration of contaminant plume.</p>
Containment			
Physical Barriers			
Deep Soil Mixing Walls	<p>Deep soil mixing consists of mixing cement with contaminated soil in situ using augers to form solidified soil cylinders. The process is repeated to form adjacent, overlapping cylinders or sometimes a double row of cylinders. When carefully constructed to provide complete overlap of the cylinders (as viewed from above) the cylinders form a honeycomb-shaped low permeability barrier. Deep soil mixing is a proven technology that can be used for depths of up to 150 feet. Verification of vertical alignment combined with constant quality assurance is necessary to assure continuity.</p>	<p>No – PR-R1 No – Roza 2</p>	<p>None of these treatment options are retained for either PR-R1 or R2 due to depth of installation and because these treatments would not provide any additional support in meeting RAOs. Any containment barrier would also have include pumping and treating the water, which if pumping and treating is selected for the site, then a barrier wall would not aid in a way that would justify the expense and technical difficulties of installation.</p>

Table 2.5-3 Screening of Technologies and Process Options for Groundwater (cont.)

Process Option	Description(s)	Retained	Rationale/ Application
Sheet Pile Walls	Sheet piles act as a barrier to groundwater and NAPL movement in a manner similar to slurry walls. However, the construction and installation methods are different. Sheet pile walls are typically made of metal sheets driven from the surface into the subsurface soils. Heavy equipment is required to drive the piles. As with slurry wall, sheet pile requires keying into bedrock. Lateral leakage at the wall component joints is also a potential concern, especially if the soils have relatively high penetration resistance, which causes the walls to bend or twist as they are driven into the subsurface.	No – PR-R1 No – Roza 2	See “Deep Soil Mixing”
Slurry Walls	Slurry walls have been used for decades, so the equipment and methodology are readily available and well known; however, the process of designing the proper mix of wall materials to contain specific contaminants is less well developed. Excavation and backfilling of the trench is critical and requires experienced contractors. These subsurface barriers consist of a vertically excavated trench that is filled with a slurry. The slurry hydraulically shores the trench to prevent collapse and forms a filter cake to reduce groundwater flow. Slurry walls often are used where the waste mass is too large for treatment and where soluble and mobile constituents pose an imminent threat to a source of drinking water.	No – PR-R1 No – Roza 2	See “Deep Soil Mixing”
Oil Filling of Bedrock Fissures	Prevent TCE already in bedrock fractures from becoming mobile and if TCE were entering the groundwater from the vadose zone, this treatment would prevent accumulation in bedrock fractures.	No – PR-R1 No – Roza 2	Too wide of an area to effectively implement
Groundwater Extraction and Collection			
Pumping for Hydraulic Control**	Possible objectives of groundwater pumping include removal of dissolved contaminants from the subsurface, and containment of contaminated groundwater to prevent migration. The criteria for well design, pumping system, and treatment are dependent on the physical site characteristics and contaminant type. Actual treatment may include the design of a train of processes such as gravity segregation, air strippers, carbon systems tailored to remove specific contaminants. Components of any groundwater extraction system are a groundwater-monitoring program to verify its effectiveness and a determination of the termination requirements. Monitoring the remediation with wells and piezometers allows the operator to make iterative adjustments to the system in response to changes in subsurface conditions caused by the remediation. Termination requirements are based on the cleanup objectives defined in the initial stage of the remedial process. The termination criteria are also dependent on the specific site aspects revealed during remedial operations.	Yes – PR-R1 Yes – Roza 2	Retained for evaluation for the possibility of the prevention of further migration of the dissolved-phase contaminant plume.
Drawdown Pumping**	Pump drawdown non-aqueous-phase liquid (NAPL) recovery systems are designed to pump NAPL and groundwater from recovery wells or trenches. Pumping removes water and lowers the water table near the extraction area to create a cone of depression. The cone of depression in the vicinity of the extraction well produces a gravity head that pushes flow of NAPL toward the well and increases the thickness of the NAPL layer in the well. Each foot of groundwater depression provides a driving head equivalent to a pressure difference of 0.45 psi. In most cases, the production of a cone of depression will increase NAPL recovery rates. (Associated process options – dual-phase extraction and physical barriers.)	No – PR-R1 No – Roza 2	Not retained for use at the site due to this process option being associated with source reduction. This option may be reconsidered if a TCE source to groundwater is discovered in the future. However, if physical barriers pass the evaluation process, then drawdown pumping may be included as a process

Table 2.5-3 Screening of Technologies and Process Options for Groundwater (cont.)

Process Option	Description(s)	Retained	Rationale/ Application option component.
Ex-Situ Treatments (assumes groundwater pumping)			
Physical/ Chemical Treatments			
Adsorption/ Absorption**	<p>Adsorption mechanisms are generally categorized as either physical adsorption, chemisorption, or electrostatic adsorption. Weak molecular forces, such as Van der Waals forces, provide the driving force for physical adsorption, while a chemical reaction forms a chemical bond between the compound and the surface of the solid in chemisorption. Electrostatic adsorption involves the adsorption of ions through Coulombic forces, and is normally referred to as ion exchange, which is addressed separately in the ion exchange modules. In liquids, interactions between the solute and the solvent also play an important role in establishing the degree of adsorption.</p> <p>The most common adsorbent is granulated activated carbon (GAC). Other natural and synthetic adsorbents include: activated alumina, forage sponge, lignin adsorption, sorption clays, and synthetic resins. Modification of GAC, such as silicone impregnated carbon, could increase removal efficiency and extend the length of operation. It may also be safer to regenerate. For this site, granular activated carbon is selected based on the best treatment of the chemical of concern.</p> <p>The duration of GAC is usually short-term; however, if concentrations are low enough, the duration may be long-term. The duration of operation and maintenance is dependent on contaminant type, concentration, and volume; regulatory cleanup requirements; and metal concentrations.</p> <p>This technology also includes the point-of-use filters already being provided to some of the residents in the affected areas.</p>	<p>Yes – PR-R1 Yes – Roza 2</p>	<p>Retained for evaluation for the remediation of contaminated groundwater. This technology does not need to be used as part of a treatment train and may be employed as a stand-alone treatment (after pumping). The factor to consider for this treatment is the cost of this technology on the low dissolved-phase concentrations in the aquifers of concern.</p> <p>In fact, a type of this technology is already effectively in use at the site.</p>
Advanced Oxidation Processes**	<p>UV oxidation is a destruction process that oxidizes organic and explosive constituents in wastewater by the addition of strong oxidizers and irradiation with UV light. Oxidation of target contaminants is caused by direct reaction with the oxidizers, UV photolysis, and through the synergistic action of UV light, in combination with ozone (O₃) and/or hydrogen peroxide (H₂O₂). If complete mineralization is achieved, the final products of oxidation are carbon dioxide, water, and salts. The main advantage of UV oxidation is that it is a destruction process, as opposed to air stripping or carbon adsorption, for which contaminants are extracted and concentrated in a separate phase. UV oxidation processes can be configured in batch or continuous flow modes, depending on the throughput under consideration. The UV oxidation process is generally done with low-pressure lamps operating at 65 watts of electricity for ozone systems and lamps operating at 15kW to 60kW for hydrogen peroxide systems.</p>	<p>Yes – PR-R1 Yes – Roza 2</p>	<p>Retained for evaluation for the remediation of contaminated groundwater. The factors to consider for this treatment are the effectiveness and/or cost of this technology on the low dissolved-phase concentrations in the aquifers of concern.</p>

Table 2.5-3 Screening of Technologies and Process Options for Groundwater (cont.)

Process Option	Description(s)	Retained	Rationale/ Application
Air Stripping**	<p>Air stripping is a full-scale technology in which volatile organics are partitioned from groundwater by greatly increasing the surface area of the contaminated water exposed to air. Types of aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration.</p> <p>Air stripping involves the mass transfer of volatile contaminants from water to air. For groundwater remediation, this process is typically conducted in a packed tower or an aeration tank. The typical packed tower air stripper includes a spray nozzle at the top of the tower to distribute contaminated water over the packing in the column, a fan to force air countercurrent to the water flow, and a sump at the bottom of the tower to collect decontaminated water. Auxiliary equipment that can be added to the basic air stripper includes an air heater to improve removal efficiencies; automated control systems with sump level switches and safety features, such as differential pressure monitors, high sump level switches, and explosion-proof components; and air emission control and treatment systems, such as activated carbon units, catalytic oxidizers, or thermal oxidizers. Packed tower air strippers are installed either as permanent installations on concrete pads or on a skid or a trailer.</p> <p>The eventual duration of cleanup using an air stripping system may be tens of years and depends on the capture of the entire plume from the groundwater.</p>	<p>Yes – PR-R1 Yes – Roza 2</p>	<p>Retained for evaluation for the remediation of contaminated groundwater. The vapor residuals may not need to be treated depending on the state or local regulations and the location of the treatment area. The factors to consider for this treatment are the effectiveness and/or cost of this technology on the low dissolved-phase concentrations in the aquifers of concern.</p>
Deep Well Injection**	<p>A typical injection well consists of concentric pipes, which extend several thousand feet down from the surface level into highly saline, permeable injection zones that are confined vertically by impermeable strata. The outermost pipe or surface casing extends below the base of any underground sources of drinking water (USDW) and is cemented back to the surface to prevent contamination of the USDW. Directly inside the surface casing is a long string casing that extends to and sometimes into the injection zone. This casing is filled in with cement all the way back to the surface in order to seal off the injected waste from the formations above the injection zone back to the surface. The casing provides a seal between the wastes in the injection zone and the upper formations. The waste is injected through the injection tubing inside the long string casing either through perforations in the long string or in the open hole below the bottom of the long string. The space between the string casing and the injection tube, called the annulus, is filled with an inert, pressurized fluid, and is sealed at the bottom by a removable packer preventing injected wastewater from backing up into the annulus.</p>	<p>Yes – PR-R1 Yes – Roza 2</p>	<p>Retained for evaluation for the prevention of further dissolved contaminant migration of and the prevention of source material migration into the groundwater.</p> <p>This technology will likely be used as part of a treatment train, rather than as a stand-alone treatment.</p>
Separation**	<p>Separation processes seek to detach contaminants from their medium (i.e., groundwater and/or binding material that contain them). Ex-situ separation of waste stream can be performed by many processes:</p> <ul style="list-style-type: none"> • Distillation. • Filtration/ultrafiltration/ microfiltration. • Freeze crystallization. • Membrane pervaporation. 	<p>No – PR-R1 No – Roza 2</p>	<p>Not retained for use at the site based on the lack of a need for the technology due to groundwater characteristics.</p>

Table 2.5-3 Screening of Technologies and Process Options for Groundwater (cont.)

Process Option	Description(s)	Retained	Rationale/ Application
	<ul style="list-style-type: none"> Reverse osmosis. 		
Sprinkler Irrigation**	Sprinkler irrigation is a relatively simple treatment technology used to volatilize VOCs from contaminated wastewater. The process involves the pressurized distribution of VOC-laden water through a standard sprinkler irrigation system. Sprinkler irrigation transfers VOCs from the dissolved aqueous phase to the vapor phase, whereby the VOCs are released directly to the atmosphere.	No – PR-R1 No – Roza 2	Not retained for use at this site based on possible concern over exposure to the TCE vapors from the sprayed water, conveyance of water to areas for irrigation, difficulty in balancing recharge for managing water levels during pumping, and lack of year-round operation for controlling plume.
Biological Treatment			
Bioreactors**	Bioreactors degrade contaminants in water with micro-organisms. Such systems, as part of a pump and treat system, can include aerobic or anaerobic treatment, suspended or attached particles, and processed in continuous or batched processes. Contaminated groundwater is circulated in an aeration basin where a microbial population aerobically degrades organic matter and produces CO ₂ , H ₂ O, and new cells. The cells form a sludge, which is settled out in a clarifier, and is either recycled to the aeration basin or disposed. Aerobic treatment is better for unsubstituted nonaromatics (TCE is substituted), materials with unsaturated bonds (TCE has an unsaturated bond), and soluble organics (solubility of TCE at is 1 g/L of water at 25 °C).	Yes – PR-R1 Yes – Roza 2	Retained for evaluation for the remediation of contaminated groundwater.
Constructed Wetlands**	The constructed wetlands-based treatment technology uses natural geochemical and biological processes inherent in an artificial wetland ecosystem to accumulate and remove metals and other contaminants from influent water.	No – PR-R1 No – Roza 2	Not retained for use at the site due to arid local climate.
Thermal Treatment			
No Ex-Situ Thermal Technologies Identified			
In-Situ Treatment			
Physical/ Chemical Treatment			
Air Sparging**	<p>Air sparging is an in-situ technology in which air is injected through a contaminated aquifer. Injected air traverses horizontally and vertically in channels through the soil column, creating an underground stripper that removes contaminants by volatilization. This injected air helps to flush (bubble) the contaminants up into the unsaturated zone where a vapor extraction system is usually implemented in conjunction with air sparging to remove the generated vapor phase contamination. This technology is designed to operate at high flow rates to maintain increased contact between groundwater and soil and strip more groundwater by sparging.</p> <p>Oxygen added to contaminated groundwater and vadose zone soils can also enhance biodegradation of contaminants below and above the water table.</p> <p>Air sparging has a medium to long duration, which may last, generally, up to a few years.</p>	No – PR-R1 No – Roza 2	Not retained for use at the site due to presence of Ringold as a confining layer for the shallow basalt aquifer and the dense interior of Roza 1 as a confining layer for Roza 2.

Table 2.5-3 Screening of Technologies and Process Options for Groundwater (cont.)

Process Option	Description(s)	Retained	Rationale/ Application
	The target contaminant groups for air sparging are VOCs (such as TCE) and fuels. Methane can be used as an amendment to the sparged air to enhance cometabolism of chlorinated organics (such as TCE).		
Bioslurping**	<p>Bioslurping is the adaptation and application of vacuum-enhanced dewatering technologies to remediate hydrocarbon-contaminated sites. Bioslurping utilizes elements of both, bioventing and free product recovery, to address two separate contaminant media. Bioslurping combines elements of both technologies to simultaneously recover free product and bioremediate vadose zone soils. Bioslurping can improve free-product recovery efficiency without extracting large quantities of groundwater. In bioslurping, vacuum-enhanced pumping allows LNAPL to be lifted off the water table and released from the capillary fringe. This minimizes changes in the water table elevation, which minimizes the creation of a smear zone. Bioventing of vadose zone soils is achieved by drawing air into the soil due to withdrawing soil gas via the recovery well. The system is designed to minimize environmental discharge of groundwater and soil gas. When free-product removal activities are completed, the bioslurping system is easily converted to a conventional bioventing system to complete the remediation.</p> <p>Operation and maintenance duration for bioslurping varies from a few months to years, depending on specific site condition.</p>	No – PR-R1 No – Roza 2	Not retained for use at the site due to this technology being most applicable to groundwater source areas. If in the future, a treatable groundwater source is encountered, this technology may be reconsidered (most likely for PR-R1 only).
Chemical Oxidation**	The chemical oxidants most commonly employed to date include peroxide (including Fenton's Reagent), ozone, and permanganate. These oxidants have been able to cause the rapid and complete chemical destruction of many toxic organic chemicals; other organics are amenable to partial degradation as an aid to subsequent bioremediation. In general the oxidants have been capable of achieving high treatment efficiencies (e.g., > 90 percent) for unsaturated aliphatic (e.g., trichloroethene [TCE]), with very fast reaction rates (90 percent destruction in minutes). Permanganate is the most applicable oxidizer for this site due to the others' need for acidic conditions (pH between 2 to 4). Permanganate systems are effective over a pH range of 3.5 to 12 (typical site pH range is between 7 and 8). Field applications have clearly affirmed that matching the oxidant and in-situ delivery system to the chemicals of concern (COCs) and the site conditions is the key to successful implementation and achieving performance goals.	Yes – PR-R1 Yes – Roza 2	<p>Permanganate is retained for evaluation.</p> <p>This technology does not need to be used as part of a treatment train and may be employed as a stand-alone treatment. The factors to consider for this treatment are the effectiveness and/or scale of this technology on a dissolved-phase plume.</p>
Dual Phase Extraction**	<p>Dual-phase extraction (DPE), also known as multi-phase extraction, vacuum-enhanced extraction, or sometimes bioslurping, is a technology that uses a high vacuum system to remove various combinations of contaminated groundwater, separate-phase petroleum product, and hydrocarbon vapor from the subsurface. Extracted liquids and vapor are treated and collected for disposal, or re-injected to the subsurface (where permissible under applicable state laws).</p> <p>In DPE systems for liquid/vapor treatment, a high vacuum system is utilized to remove liquid and gas from low permeability or heterogeneous formations. The vacuum extraction well includes a screened section in the zone of contaminated soils and groundwater. It removes contaminants from above and below the water table. The system lowers the water table around the well, exposing more of the formation. Contaminants in the newly exposed vadose zone are then accessible to vapor extraction. Once above ground, the extracted vapors or liquid-phase organics</p>	No – PR-R1 No – Roza 2	Not retained for use at this site due to this technology being most applicable to groundwater source areas. If in the future, a treatable groundwater source is encountered, this technology may be reconsidered (most likely for PR-R1 only).

Table 2.5-3 Screening of Technologies and Process Options for Groundwater (cont.)

Process Option	Description(s)	Retained	Rationale/ Application
	and groundwater are separated and treated. DPE for liquid/vapor treatment is generally combined with bioremediation, air sparging, or bioventing when the target contaminants include long-chained hydrocarbons. Use of dual phase extraction with these technologies can shorten the cleanup time at a site. It also can be used with pump-and-treat technologies to recover groundwater in higher-yielding aquifers.		
In-Well Air Stripping**	<p>In-well air stripping is a technology whereby air is injected into a vertical well that has been screened at two depths. The lower screen is set in the groundwater-saturated zone, and the upper screen is in the unsaturated (vadose) zone. Pressurized air is injected into the well below the water table, aerating the water. The aerated water rises in the well and flows out of the system at the upper screen. Contaminated groundwater is drawn into the system at the lower screen. The volatile organic compounds (VOCs, such as TCE) vaporize within the well at the top of the water table, as the air bubbles out of the water. The vapors are drawn off by a soil vapor extraction (SVE) system. The partially treated groundwater is never brought to the surface; it is forced into the unsaturated zone, and the process is repeated as water follows a hydraulic circulation pattern or cell that allows continuous cycling of groundwater. As groundwater circulates through the treatment system in situ, contaminant concentrations are gradually reduced. In-well air stripping is a pilot-scale technology.</p> <p>Modifications to the basic in-well stripping process may involve additives injected into the stripping well to enhance biodegradation (e.g., nutrients, electron acceptors, etc.). In addition, the area around the well affected by the circulation cell (radius of influence) can be modified through the addition of certain chemicals to allow in situ stabilization of metals originally dissolved in groundwater. The duration of in-well air stripping is short- to long-term, depending contaminant concentrations, Henry's law constants of the contaminants, the radius of influence, and site hydrogeology.</p>	<p>Yes – PR-R1 Yes – Roza 2</p>	<p>Retained for evaluation for PR-R1 and Roza 2.</p> <p>The factor to consider for this treatment is the effectiveness this technology on the low dissolved-phase concentrations in the aquifers of concern.</p>

Table 2.5-3 Screening of Technologies and Process Options for Groundwater (cont.)

Process Option	Description(s)	Retained	Rationale/ Application
Passive /Reactive Treatment Walls**	<p>A permeable reaction wall is installed across the flow path of a contaminant plume, allowing the water portion of the plume to passively move through the wall. These barriers allow the passage of water while prohibiting the movement of contaminants by employing such agents as zero-valent metals, chelators (ligands selected for their specificity for a given metal), sorbents, microbes, and others. The contaminants will either be degraded or retained in a concentrated form by the barrier material. The wall could provide permanent containment for relatively benign residues or provide a decreased volume of the more toxic contaminants for subsequent treatment.</p> <p>Types of walls:</p> <p>Funnel and gate (component of a physical barrier, i.e. cutoff wall) with a selected in-situ treatment agent (for this site, zero-valent iron would likely be selected) as, or</p> <p>Iron treatment wall</p>	<p>No – PR-R1 No – Roza 2</p>	<p>None of these treatment options are retained for either PR-R1 or R2 due to depth of installation and because these treatments would not provide any additional support in meeting RAOs. Any containment barrier would also have include pumping and treating the water, which if pumping and treating is selected for the site, then a barrier wall would not aid in a way that would justify the expense and technical difficulties of installation.</p>
Zero-Valent Iron (nanoscale or microscale)	<p>Emulsified zero-valent iron for reductive dehalogenation of TCE. The emulsifying agent is vegetable oil. ZVI combined with the vegetable oil allows for the combination of the TCE to the ZVI where the TCE is reduced to its degradation products through reactions with the iron. Any remaining oil enhances reductive natural attenuation by providing a substrate as an electron donor. Sites where this technology has been used show little indication of rebound after 6 to 18 months of monitoring.</p>	<p>Yes – Roza 1 Yes – Roza 2</p>	<p>Retained</p>
Biological Treatment			
Biodegradation for Anaerobic Conditions**	<p>The rate of biodegradation of organic contaminants by microbes is increased by the concentration of electron acceptors and nutrients in groundwater, surface water, and leachate. Oxygen is the main electron acceptor for aerobic bioremediation. Nitrate serves as an alternative electron acceptor under anoxic conditions.</p> <ul style="list-style-type: none"> • Nitrate Enhancements. • Oxygen Enhancements. • Oxygen Enhancements with Hydrogen Peroxide. 	<p>No – PR-R1 No – Roza 2</p>	<p>Not retained for use at the site due to aerobic groundwater conditions.</p>

Table 2.5-3 Screening of Technologies and Process Options for Groundwater (cont.)

Process Option	Description(s)	Retained	Rationale/ Application
Biodegradation for Aerobic Conditions**	<p>Co-metabolism is one form of secondary substrate transformation in which enzymes produced for primary substrate oxidation are capable of degrading the secondary substrate fortuitously, even though the secondary substrates do not afford sufficient energy to sustain the microbial population. An emerging application involves the injection of water containing dissolved primary substrate (e.g., methane, toluene) and oxygen into ground water to support the co-metabolic breakdown of targeted organic contaminants.</p> <p>The addition of methane or methanol supports methanotrophic activity, which has been demonstrated effective to degrade chlorinated solvents, such as vinyl chloride and TCE, by co-metabolism. Although toluene, propane, and butane are used to stimulate a different class of microorganisms, not methanotrophs, they have been used successfully for supporting co-metabolism of TCE. Co-metabolic technologies may be classified as long-term technologies, which may take several years to clean up a plume.</p>	<p>Yes – PR-R1 Yes – Roza 2</p>	Retained for evaluation for PR-R1 and Roza 2.
Phytoremediation**	Phytoremediation is a set of processes that uses plants to clean contamination in groundwater and surface water. There are several ways plants can be used for the phytoremediation. These mechanisms include enhanced rhizosphere biodegradation, hydraulic control, phyto-degradation, and phyto-volatilization.	<p>No – PR-R1 No – Roza 2</p>	Not retained for use at this site due to depth to groundwater.
Thermal Treatment			
Thermal Treatments – Steam Injection	<p>Steam is forced into an aquifer through injection wells to vaporize volatile and semivolatile contaminants. Vaporized components rise to the unsaturated (vadose) zone where they are removed by vacuum extraction and then treated. Hot water or steam-based techniques include:</p> <ul style="list-style-type: none"> • Steam injection and vacuum extraction (SIVE), • In-situ steam-enhanced extraction (ISEE), and • Steam-enhanced recovery process (SERP). <p>Hot water or steam flushing/stripping is a proven pilot-scale technology for chlorinated solvents. In situ biological treatment may follow the displacement and is continued until groundwater contaminant concentrations satisfy statutory requirements. The process can be used to retard downward and lateral migration of organic contaminants. The process is applicable to shallow and deep contaminated areas and readily available mobile equipment can be used. Hot water/steam injection is typically short to medium duration, lasting a few weeks to several months.</p>	<p>No – PR-R1 No – Roza 2</p>	Not retained for use at this site due to this technology being most applicable to source areas. If in the future, a treatable source is encountered, this technology may be reconsidered.
Thermal Treatments – Electrical Resistant Heating	An electrical current is delivered to the saturated zone via steel wells. The heat from the current heats the groundwater to steam and volatilizes the chemicals of concern. The steam vapor is then extracted and treated.	<p>No – PR-R1 No – Roza 2</p>	Not retained for use at this site due to this technology being most applicable to source areas. If in the future, a treatable source is encountered, this technology may be reconsidered.

Table 2.5-3 Screening of Technologies and Process Options for Groundwater (cont.)

Process Option	Description(s)	Retained	Rationale/ Application
Treatment Technology Components			
Fluid Delivery Systems			
Vertical Wells***	Permanent wells used to distribute chemicals or other fluids (i.e., air, nutrients, etc.) into the aquifer to be treated.	Yes – PR-R1 Yes – Roza 2	Retained unless all treatments requiring vertical wells are evaluated out of consideration.
Horizontal Wells**	Drilling techniques are used to position wells horizontally to reach contaminants not accessible by vertical drilling. Directional drilling may be used to enhance other in-situ or in-well technologies such as groundwater pumping, bioventing, SVE, soil flushing, and in-well air stripping.	Yes – PR-R1 Yes – Roza 2	Retained unless all treatments requiring directional wells are evaluated out of consideration.
Direct-Push Injection Points**	Temporary wells (installed used direct-push technology) used to distribute chemicals or other fluids (i.e., air, nutrients, etc.) into the aquifer.	No – PR-R1 No – Roza 2	Not retained for use at this site due to difficulty of implementing the technology component in the site's geology.
System Enhancements			
Circulating Wells**	<p>Circulating wells (CWs) provide a technique for subsurface remediation by creating a three-dimensional circulation pattern of the groundwater. Groundwater is drawn into a well through one screened section and is pumped through the well to a second screened section where it is reintroduced to the aquifer. The flow direction through the well can be specified as either upward or downward to accommodate site-specific conditions. Because groundwater is not pumped above ground, pumping costs and permitting issues are reduced and eliminated, respectively. Also, the problems associated with storage and discharge are removed.</p> <p>CW systems can provide treatment inside the well, in the aquifer, or a combination of both. For effective in-well treatment, the contaminants must be adequately soluble and mobile so they can be transported by the circulating groundwater. Because CW systems provide a wide range of treatment options, they provide some degree of flexibility to a remediation effort.</p>	Yes – PR-R1 Yes – Roza 2	Retained unless all treatments that could benefit from circulating well are evaluated out of consideration.
Hydrofracturing (Enhancements) **	<p>Hydrofracturing is a pilot-scale technology in which pressurized water is injected to increase the permeability of consolidated material or relatively impermeable unconsolidated material. Fissures created in the process are filled with a porous medium that can facilitate bioremediation and/or improve extraction efficiency. Fractures promote more uniform delivery of treatment fluids and accelerated extraction of mobilized contaminants. Typical applications are linked with soil vapor extraction, in situ bioremediation, and pump-and-treat systems.</p> <p>The hydraulic fracturing process can be used in conjunction with soil vapor extraction technology to enhance recovery. Hydraulically induced fractures are used to deliver fluids, substrates, and nutrients for in situ bioremediation applications.</p>	No – PR-R1 No – Roza 2	This technology is not applicable to the site because increasing the permeability within PR-R1 and Roza 2 aquifers does not aid in reducing the dissolved-phase contamination or plume. However, if source is discovered within the dense flow interior of R1 or R2, this technology may reconsider to improve permeability for the possible treatment at a source.

Table 2.5-3 Screening of Technologies and Process Options for Groundwater (cont.)

Process Option	Description(s)	Retained	Rationale/ Application
Air Emissions/Off-Gas Treatment			
High Energy Destruction**	The high-energy destruction technology is one of many approaches toward decontamination of air emission off-gases prior to atmospheric release. The objective of the HEC technology is to provide a standalone, field-portable means of treating off-gases produced during other remedial operations.	Yes – PR-R1 Yes – Roza 2	Retained for evaluation as part of a treatment train.
Membrane Separation**	A high-pressure membrane separation system has been designed by DOE to treat feedstreams that contain dilute concentrations of VOCs. The organic vapor/air separation technology involves the preferential transport of organic vapors through a nonporous gas separation membrane (a diffusion process analogous to pumping saline water through a reverse osmosis membrane). In this system, the feed stream is compressed and sent to a condenser where the liquid solvent is recovered. The condenser bleed stream, which contains approximately 5,000 ppm of the VOC, is then sent to the membrane module. The membrane module is comprised of spiral-wound modules of thin film membranes separated by plastic mesh spacers. The membrane and the spacers are wound spirally around a central collection pipe. In the membrane module the stream is further concentrated to 3% VOC. The concentrated stream is then returned to the compressor for further recovery in the condenser.	Yes – PR-R1 Yes – Roza 2	Retained for evaluation as part of a treatment train.
Oxidation**	Oxidation equipment (thermal or catalytic) is used for destroying contaminants in the exhaust gas from air strippers and SVE systems. Thermal oxidation units are typically single chamber, refractory-lined oxidizers equipped with a propane or natural gas burner and a stack. Lightweight ceramic blanket refractory is used because many of these units are mounted on skids or trailers. If gasoline is the contaminant, heat exchanger efficiencies are limited to 25 to 35%, and preheat temperatures are maintained below 180 °C (530 °F) to minimize the possibility of ignition occurring in the heat exchanger. Flame arrestors are always installed between the vapor source and the thermal oxidizer. Burner capacities in the combustion chamber range from 0.5 to 2 million BTUs per hour. Operating temperatures range from 760 to 870 °C (1,400 °C to 1,600 °F), and gas residence times are typically 1 second or less.	Yes – PR-R1 Yes – Roza 2	Retained for evaluation as part of a treatment train.
Vapor Phase Carbon Adsorption**	Vapor-phase carbon adsorption is a remediation technology in which pollutants are removed from air by physical adsorption onto activated carbon grains. Carbon is "activated" for this purpose by processing the carbon to create porous particles with a large internal surface area (300 to 2,500 square meters or 3,200 to 27,000 square feet per gram of carbon) that attracts and adsorbs organic molecules as well as certain metal and inorganic molecules. Commercial grades of activated carbon are available for specific use in vapor-phase applications. Carbon can be used in conjunction with steam reforming. Steam reforming is a technology designed to destroy halogenated solvents (such as carbon tetrachloride, CCl ₄ , and chloroform, CHCl ₃) adsorbed on activated carbon by reaction with superheated steam (steam reforming).	Yes – PR-R1 Yes – Roza 2	Retained for evaluation as part of a treatment train.

Table 2.5-3 Screening of Technologies and Process Options for Groundwater (cont.)

Key:

°C – degrees Celsius

°F – degrees Fahrenheit

BTUs – British Thermal Units

CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act

COC – chemical of concern

CW – circulating wells

DOE – U.S. Department of Energy

DPE – dual-phase extraction

g/L – grams per liter

GAC – granulated activated carbon

H₂O₂ – hydrogen peroxide

HEC – high energy destruction

IC – institutional control

ISEE – In-situ steam-enhanced extraction

kW – kilowatt

LNAPL – light non-aqueous-phase liquid

NAPL – non-aqueous-phase liquid

PR-R1 – Priest Rapids-Roza 1

R2 – Roza 2

RAO – remedial action objective

SERP – steam-enhanced recovery process

SIVE – steam injection and vacuum extraction

SVE – soil vapor extraction

TCE – trichloroethene

USDW – underground sources of drinking water

UV – ultra violet

VOC – volatile organic compound

ZVI – zero-valent iron

Table 2.6-1 Evaluation of Retained Process Options for Subsurface Soil and Groundwater

Process Option	Description	E	I	C	Retained	Evaluation Comments
No Action						
No Action	No Action.	O	O	O	Yes – Sub-surface soil Yes – GW	No Action is a required consideration and provides the baseline to compare other alternatives. This is the only soil process option evaluated.
Institutional Controls						
Governmental						
Zoning Local Permits Police power ordinances Groundwater use restrictions Condemnation of property	More details to be determined.	TBD	TBD	TBD	Yes – PR-R1 Roza 2	Although the details of these process options are not currently known, the options are principally retained for further analysis. IC details will be filled in all related tables as ICs are understood.
Proprietary Controls						
Easements Covenants Equitable Servitude Reversionary Interest State Use Restrictions Conversation Easements	More details to be determined.	TBD	TBD	TBD	Yes – PR-R1 Roza 2	Although the details of these process options are not currently known, the options are principally retained for further analysis. IC details will be filled in all related tables as ICs are understood.
Enforcement Tools						
Administrative Orders Consent Decrees	More details to be determined.	TBD	TBD	TBD	Yes – PR-R1 Roza 2	Although the details of these process options are not currently known, the options are principally retained for further analysis. IC details will be filled in all related tables as ICs are understood.
Informational Devices						
Deed Notices State registries of hazardous waste sites Advisories Educational programs	More details to be determined.	TBD	TBD	TBD	Yes – PR-R1 Roza 2	Although the details of these process options are not currently known, the options are principally retained for further analysis. IC details will be filled in all related tables as ICs are understood.

Table 2.6-1 Evaluation of Retained Process Options for Subsurface Soil and Groundwater (cont.)

Process Option	Description	E	I	C	Retained	Evaluation Comments
Other Controls						
Alternative Residential Water Supply						
Connection to City of Moses Lake water	Connect water user to City of Moses Lake existing or extended water line .	+	+	+	Yes – PR-R1 Roza 2	Alternate water supply selection details to be discussed in chapter 3.
Connection to other water purveyor system	Connect water user to other water purveyor's existing or extended water lines.	+	+	+	Yes – PR-R1 Roza 2	
New Well Installation	Install new well to replace existing well with contamination above MCL for TCE.	+	o	-	Yes – PR-R1 Roza 2	
Provided Water	Provide potable water through a commercial service, such as bottled water.	-	+	-	No – PR-R1 Roza 2	Not retained for use at the site due to high O&M costs and provided water not being a long-term solution.
Individual Well Treatment						
Activated Carbon Filter	Install and maintain point-of-use individual well treatment as short-term protective action or as last-resort long-term solution.	+	+	o	Yes – PR-R1 Roza 2	See details in Ex-Situ Treatment process option evaluations
Low-Profile Air Stripper		+	+	o	Yes – PR-R1 Roza 2	
UV Filtration System		o	o	-	No – PR-R1 Roza 2	
Surface barriers in Area of Potential Concern						
Fencing	Passive technologies designed to prevent groundwater-obtaining activities at the surface above the highest areas of contaminated groundwater.	o	+	+	Yes – PR-R1 Roza 2	Although no clear application stands out at this point of the evaluation, fencing is retained to likely be used in conjunction with ICs.
Long-Term Monitoring						
Long-Term Monitoring – PR-R1 and Roza 2	Long-term monitoring of contaminant migration away from an identified source area.	o	+	-	Yes – PR-R1 Roza 2	This is the only process option for long-term monitoring, which is retained for any and all technologies retained.

Table 2.6-1 Evaluation of Retained Process Options for Subsurface Soil and Groundwater (cont.)

Process Option	Description	E	I	C	Retained	Evaluation Comments
Natural Attenuation with Monitoring						
Natural Attenuation with monitoring – PR-R1 and Roza 2	This process option will be part of an overall monitoring program with the intention of natural attenuation to aid in reducing contaminant concentrations.	o	+	o	Yes – PR-R1 Yes – Roza 2	<p><u>Effectiveness Factors:</u></p> <ol style="list-style-type: none"> 1. ICs are still required for the site, and reductive dechlorination is not shown to be a major component of natural attenuation at the Site. 2. Intermediate degradation products may be more mobile and more toxic than the original contaminant; and contaminants may migrate before they can be attenuated. 3. Natural attenuation is well understood and a fully developed technology. 4. Longer time frames compared to active remediation. <p><u>Implementability Factors:</u></p> <ul style="list-style-type: none"> • No obstructions to implementability. <p><u>Cost Factors:</u></p> <ul style="list-style-type: none"> • Long-term monitoring and modeling with associated costs for both.
Containment						
Groundwater Extraction and Collection						
Pumping for Hydraulic Control – PR-R1 and Roza 2	Localized extraction and collection with potential for ex-situ treatment of groundwater. Groundwater extraction is a widely available, fully developed technology that is usually part of a treatment train where liquid residuals are produced (the extracted water).	o	o	-	Yes – PR-R1 Yes – Roza 2	<p><u>Effectiveness Factors:</u></p> <ol style="list-style-type: none"> 1. Design challenges for capturing contaminant as predicted. 2. Potential community water use and infrastructure impacts. 3. While a fully developed technology, there is variability in how proven and reliable these systems are long-term. 4. Potentially long time to achieve remediation goals. <p><u>Implementability Factors:</u></p> <ol style="list-style-type: none"> 1. Technical challenges exist for design of pumping system over wide areas and two aquifers simultaneously. 2. Extensive construction required. 3. Persistent residual contaminant saturation and biofouling is common in extraction system. 4. Frequent and extensive maintenance usually required.

Table 2.6-1 Evaluation of Retained Process Options for Subsurface Soil and Groundwater (cont.)

Process Option	Description	E	I	C	Retained	Evaluation Comments
						<p>5. System reliability is variable.</p> <p><u>Cost Factors:</u></p> <p>1. Capital Intensive. 2. O&M Intensive. 3. Worse overall costs.</p>
Ex-Situ Treatment (assumes groundwater pumping)						
Physical/Chemical Treatment						
Adsorption/ Absorption – PR-R1 and Roza 2	<p>The target contaminants groups for adsorption/absorption processes are most organic contaminants and selected inorganic contaminants from liquid and gas streams. For granular activated carbon, groundwater is pumped through a series of canisters or columns containing activated carbon to which dissolved organic contaminants adsorb. Periodic replacement or regeneration of saturated carbon is required. The target contaminant groups for carbon adsorption are hydrocarbons, SVOCs, and explosives. Limited effectiveness may be achieved on halogenated VOCs and pesticides. Liquid phase carbon adsorption is effective for removing contaminants at low concentrations (less than 10 mg/L) from water at nearly any flow rate. Carbon adsorption is particularly effective for polishing water discharges from other remedial technologies to attain regulatory compliance. Carbon adsorption systems can be deployed rapidly, and contaminant removal efficiencies are high. Logistic and economic disadvantages arise from the need to transport and decontaminate spent carbon.</p>	<p>+</p> <p>o</p> <p>+</p> <p>-</p>	<p>+</p> <p>+</p> <p>-</p> <p>+</p>	<p>+</p> <p>-</p> <p>-</p>	<p>Yes – PR-R1 Yes – Roza 2</p>	<p><u>Effectiveness Factors:</u></p> <p>1. Effective on low contaminant concentrations and better for treatment of halogenated VOCs. 2. No uncommon impacts to humans during action for all ex-situ treatments (see “Pumping for Hydraulic Control”). 3. A proven and fully developed technology. 4. Worse cleanup time.</p> <p><u>Implementability Factors:</u></p> <p>1. Better availability, but type, pore size, and quality of the carbon, as well as the operating temperature, will impact process performance. Vendor expertise for carbon selection should be consulted. 2. No treatment train required. 3. Solid residuals produced; all spent carbon eventually needs to be properly disposed. 4. Better system reliability and maintainability.</p> <p><u>Cost Factors:</u></p> <p>1. Not capital cost intensive. 2. O&M cost intensive. 3. Worse overall costs.</p>

Table 2.6-1 Evaluation of Retained Process Options for Subsurface Soil and Groundwater (cont.)

Process Option	Description	E	I	C	Retained	Evaluation Comments
Advanced UV Oxidation Processes – PR-R1 and Roza 2	Applicable to almost any organic contaminant that is reactive with the hydroxyl radical (the list of reactive chemicals includes chlorinated hydrocarbons like TCE). In fact, TCE is typically destroyed rapidly because it is considered to be easily oxidized.	o o + -	+ - o o	- - o	No – PR-R1 No – Roza 2	<p><u>Effectiveness Factors:</u></p> <ol style="list-style-type: none"> 1. Better for treatment of halogenated VOCs, but possible incomplete destruction of TCE resulting in more toxic chemical production and additional treatment. 2. No uncommon impacts to humans during action for all ex-situ treatments (see “Pumping for Hydraulic Control”). 3. A proven and fully developed technology. 4. Worse cleanup time. <p><u>Implementability Factors:</u></p> <ol style="list-style-type: none"> 1. Better availability, but special handling may be required. 2. Treatment train required. 3. Vapor residuals produced. 4. Average system reliability and maintainability. <p><u>Cost Factors:</u></p> <ol style="list-style-type: none"> 1. Capital cost intensive. 2. O&M (higher energy costs) intensive. 3. Average overall costs.
Air Stripping – PR-R1 and Roza 2	Air stripping is used to separate VOCs from water. Henry's law constant is used to determine whether air stripping will be effective. Generally, organic compounds with constants greater than 0.01 atmospheres - m ³ /mol are considered amenable to stripping. Some compounds that have been successfully separated from water using air stripping include BTEX, chloroethane, TCE, DCE, and PCE.	+ o + -	+ o o +	+ - +	Yes – PR-R1 Yes – Roza 2	<p><u>Effectiveness Factors:</u></p> <ol style="list-style-type: none"> 1. Effective on low contaminant concentrations, better for treatment of halogenated VOCs. 2. No uncommon impacts to humans during action for all ex-situ treatments (see “Pumping for Hydraulic Control”). 3. Well known method and successfully used, particularly on TCE plumes; fully developed technology. 4. Worse cleanup time. <p><u>Implementability Factors:</u></p> <ol style="list-style-type: none"> 1. Better availability and more design dependent. 2. Treatment train may be required.

Table 2.6-1 Evaluation of Retained Process Options for Subsurface Soil and Groundwater (cont.)

Process Option	Description	E	I	C	Retained	Evaluation Comments
						3. Vapor residuals produced. 4. Better system reliability and maintainability. <u>Cost Factors:</u> 1. Not capital cost intensive. 2. O& M cost intensive. 3. Better overall costs.
Deep Well Injection – PR-R1 and Roza 2	<p>Deep well injection is a liquid waste disposal technology. This alternative uses injection wells to place treated or untreated liquid waste into geologic formations that have no potential to allow migration of contaminants into potential potable water aquifers.</p> <p>The target contaminant groups for deep well injection are VOCs, SVOCs, fuels, explosives, and pesticides. However, existing permitted deep well injection facilities are limited to a narrow range of specific wastes. Success at expanding existing permits to manage hazardous wastes seems unlikely.</p>	- o - -	- + - o	+ + +	No – PR-R1 No – Roza 2	<u>Effectiveness Factors:</u> 1. Worse effectiveness: doesn't actually treat, simply disposes of contaminated water. 2. No uncommon impacts to humans during action for all ex-situ treatments (see "Pumping for Hydraulic Control"). 3. Not a widely-used or encouraged technology; fully developed. 4. Worse treatment time. <u>Implementability Factors:</u> 1. Extensive assessments must be completed prior to receiving approval from regulatory agency. 2. No treatment train required. 3. Solid and liquid residuals produced. 4. Average system reliability and maintainability. <u>Cost Factors:</u> 1. Not capital costs intensive. 2. Not O&M intensive. 3. Better overall costs.

Table 2.6-1 Evaluation of Retained Process Options for Subsurface Soil and Groundwater (cont.)

Process Option	Description	E	I	C	Retained	Evaluation Comments
Biological Treatment						
Bioreactors – PR-R1 and Roza 2	Bioreactors are used primarily to treat SVOCs, fuel hydrocarbons, and any biodegradable organic material. Successful pilot-scale field studies have been conducted on some halogenated compounds, such as PCP, chlorobenzene and dichloro-benzene isomers. Bioreactors with cometabolites are used to treat PCBs, halogenated VOCs, and SVOCs in extracted groundwater. Bioreactors are a long-term technology. The process may take up to several years.	o o + -	- - - -	- + +	No – PR-R1 No – Roza 2	<u>Effectiveness Factors:</u> <ol style="list-style-type: none"> 1. Dilute groundwater may not support microbial growth and may require nutrient addition; better for treatment of halogenated VOCs. 2. No uncommon impacts to humans during action for all ex-situ treatments (see “Pumping for Hydraulic Control”). 3. Fully developed technology. 4. Worse treatment time. <u>Implementability Factors:</u> <ol style="list-style-type: none"> 1. Worse availability. 2. Treatment train required; discharge of effluent may still be regulated; vapor treatment may be required. 3. Solid and vapor residuals produced. 4. Worse system reliability and maintainability; nuisance micro-organisms may preferentially colonize bioreactors. <u>Cost Factors:</u> <ol style="list-style-type: none"> 1. Capital cost intensive. 2. Not O&M intensive. 3. Better overall costs.
In-Situ Treatment						
Physical/Chemical Treatment						
In-Situ Chemical Oxidation (ISCO) – PR-R1 and Roza 2	ISCO systems are reliant upon accurate system designs in order to be more effective than other in-situ treatments. Given the relatively indiscriminate and rapid rate of reaction of the oxidants with the reduced substances, the method of delivery and distribution throughout a subsurface region is of paramount importance. (Process option components: vertical and horizontal injection wells.) Two types of ISCO are considered for this site:	+ o + +	+ + + o	- - o	Yes – PR-R1 Yes – Roza 2	<u>Effectiveness Factors:</u> <ol style="list-style-type: none"> 1. Source reduction or plume treatment; treating COCs where biological treatment is not effective; average for treatment of halogenated VOCs. 2. Possible impacts to humans during action could be purplish colored water or slight orange from any additional iron being oxidized.

Table 2.6-1 Evaluation of Retained Process Options for Subsurface Soil and Groundwater (cont.)

Process Option	Description	E	I	C	Retained	Evaluation Comments
	<ul style="list-style-type: none"> • KMnO_4 – potassium permanganate • Zero-valent iron (ZVI), nanoscale or microscale <p>A determination of which process should be selected should be made at the remedial design phase of the project. KMnO_4 and ZVI are relatively more stable and more persistent in the subsurface and can migrate by diffusive processes. ISCO systems can also affect the subsurface with reduced permeability, mobilization of metals, toxic byproducts, evolution of heat and gas, and biological perturbation.</p>					<p>3. Fully developed technology.</p> <p>4. Better cleanup time.</p> <p><u>Implementability Factors:</u></p> <p>1. Better availability; implementability can be tailored to be site-specific with relatively simple and available equipment.</p> <p>2. No associated treatment train.</p> <p>3. No residuals produced.</p> <p>4. Average system reliability and maintainability.</p> <p><u>Cost Factors:</u></p> <p>1. Capital cost intensive.</p> <p>2. O&M intensive.</p> <p>3. Average overall costs.</p>
In-Well Air-Stripping – PR-R1 and Roza 2	<p>As groundwater circulates through the treatment system in-situ, contaminant concentrations are gradually reduced. This technology could be applied to either aquifer, and this technology would also benefit from the high permeability of the alluvial overburden. (System components: circulating wells.)</p> <p>Modifications to the basic in-well stripping process may involve additives injected into the stripping well to enhance biodegradation (e.g., nutrients, electron acceptors, etc.). In addition, the area around the well affected by the circulation cell (radius of influence) can be modified through the addition of certain chemicals to allow in situ stabilization of metals originally dissolved in groundwater. The duration of in well, air stripping is short-to long-term, depending on contaminant concentrations, Henry's law constants of the contaminants, the radius of influence, and site hydrogeology.</p>	<p>o</p> <p>+</p> <p>-</p> <p>-</p>	<p>+</p> <p>+</p> <p>-</p> <p>o</p>	<p>-</p> <p>+</p> <p>o</p>	<p>No – PR-R1</p> <p>No – Roza 2</p>	<p><u>Effectiveness Factors:</u></p> <p>1. Benefit could be soil washing the unsaturated zone; only treats water in the wells; less effective for low contaminant concentrations; better for sites without NAPL (unknown at the Site); average for treatment of halogenated VOCs.</p> <p>2. No uncommon impacts to humans during action for any in-situ treatments.</p> <p>3. Pilot-scale technology.</p> <p>4. Worse cleanup time.</p> <p><u>Implementability Factors:</u></p> <p>1. Better availability.</p> <p>2. No treatment train required.</p> <p>3. Liquid and vapor residuals produced; treatment (after collection) of vapor required.</p> <p>4. Average system reliability and maintainability; more potential for system fouling due to oxidation.</p>

Table 2.6-1 Evaluation of Retained Process Options for Subsurface Soil and Groundwater (cont.)

Process Option	Description	E	I	C	Retained	Evaluation Comments
						<u>Cost Factors:</u> 1. Capital cost intensive. 2. Not O&M intensive. 3. Average overall costs.
Biological Treatment						
Biodegradation for Aerobic Conditions	<p>Cometabolism, in which microorganisms growing on one compound produce an enzyme that chemically transforms another compound on which they cannot grow, has been observed to be useful. In particular, microorganisms that degrade methane (methanotrophic bacteria) have been found to produce enzymes that can initiate the oxidation of a variety of carbon compounds.</p> <p>The addition of methane or methanol supports methanotrophic activity, which has been demonstrated effective to degrade chlorinated solvents, such as vinyl chloride and TCE, by co-metabolism.</p>	o + - -	- - + o	+ - +	No – PR-R1 No – Roza 2	<u>Effectiveness Factors:</u> 1. The addition of methane or methanol supports methanotrophic activity, which has been demonstrated effective to degrade chlorinated solvents, such as vinyl chloride and TCE, by co-metabolism; where the subsurface is heterogeneous, it is very difficult to circulate the methane solution throughout every portion of the contaminated zone. Higher permeability zones are cleaned up much faster because groundwater flow rates are greater. 2. No uncommon impacts to humans during action for any in-situ treatments. 3. This technology is still under development. 4. Co-metabolic technologies may be classified as long-term technologies which may take several years to clean up a plume. <u>Implementability Factors:</u> 1. Regulatory approval for use of specific cometabolites may be required; safety precautions (such as removing all ignition sources in the area) must be used when handling methane. 2. A surface treatment system, such as air stripping or carbon adsorption, may be required to treat extracted groundwater prior to re-injection or disposal. 3. No residuals produced. 4. Average system reliability and maintainability. <u>Cost Factors:</u> 1. Not capital cost intensive. 2. O&M intensive. 3. Better overall costs.

Table 2.6-1 Evaluation of Retained Process Options for Subsurface Soil and Groundwater (cont.)

Process Option	Description	E	I	C	Retained	Evaluation Comments
Treatment Technology Components						
Fluid Delivery Systems						
Vertical Wells –PR-R1 and Roza 2	Dependent upon treatment selection	+	+	+	Yes – PR-R1 Roza 2	Extraction, injection, monitoring.
Horizontal Wells – PR-R1 and Roza 2	Dependent upon treatment selection	+	o	o	Yes – PR-R1 Roza 2	Extraction, injection.
System Enhancements						
Circulating Wells – PR-R1 and Roza 2	Dependent upon treatment selection	o	o	o	Yes – PR-R1 Roza 2	Extraction, injection, circulation of ISCO agent.
Air Emissions Treatment						
Activated Carbon – Vapor Treatment from associated Process Option	<p>Off-gases are pumped through a series of canisters or columns containing activated carbon to which organic contaminants adsorb. Periodic replacement or regeneration of saturated carbon is required. Vapor-phase carbon adsorption is not recommended to remove high contaminant concentrations from the effluent air streams. Economics favor pretreatment of the VOC stream, followed by the use of a vapor-phase GAC system as a polishing step.</p> <p>Air stripping selected as ex-situ treatment for both PR-R1 and Roza 2.</p>	+	o + - +	+ + +	Yes	<p><u>Effectiveness Factors:</u></p> <ol style="list-style-type: none"> 1. Better for treatment of halogenated VOCs. 2. No uncommon impacts to humans during action for any in-situ treatments. 3. Fully developed technology. 4. Clean up time – N/A. <p><u>Implementability Factors:</u></p> <ol style="list-style-type: none"> 1. Better availability; relative humidity greater than 50% can reduce carbon capacity; Biological growth on carbon or high particulate loadings can reduce flow through the bed; 2. No treatment train required. 3. Solid residuals produced; spent carbon transport may require hazardous waste handling; spent carbon must be disposed of and the adsorbed contaminants must be destroyed, often by thermal treatment. 4. Better system reliability and maintainability. <p><u>Cost Factors:</u></p> <ol style="list-style-type: none"> 1. Not capital cost intensive. 2. Not O&M cost intensive. 3. Better overall costs.
High Energy Destruction	Contaminants that can be treated include most or all VOCs and SVOCs. This technique is specifically useful for destroying organics and	+	-	-	No	<p><u>Effectiveness Factors:</u></p>

Table 2.6-1 Evaluation of Retained Process Options for Subsurface Soil and Groundwater (cont.)

Process Option	Description	E	I	C	Retained	Evaluation Comments
	chlorinated solvents such as trichloroethylene (TCE). Both gas and liquid phase contaminants are treatable. The THP technology is best suited for treatment of gaseous streams with small concentrations of VOCs especially chlorinated compounds. Continued research and development is needed to better quantify treatment characteristics.	+	+	+		<ol style="list-style-type: none"> 1. Better for treatment of halogenated VOCs. 2. No uncommon impacts to humans during action for any in-situ treatments. 3. Pilot-scale technology. 4. Clean up time – N/A. <p><u>Implementability Factors:</u></p> <ol style="list-style-type: none"> 1. Worse availability. 2. No treatment train required. 3. No residuals produced. 4. Worse system reliability and maintainability. <p><u>Cost Factors:</u></p> <ol style="list-style-type: none"> 1. Capital cost intensive. 2. Not O&M cost intensive. 3. Unknown overall costs.
Membrane Separation	<p>The targeted contaminants are VOCs, carbon tetrachloride, and chloroform in gas streams. Limitations of this technology are:</p> <ul style="list-style-type: none"> • Inability to handle fouling constituents in soil. • Inability to handle fluctuations in concentrations. • Membranes are sensitive to moisture. 	<p>+</p> <p>+</p> <p>-</p> <p>-</p>	<p>-</p> <p>+</p> <p>+</p> <p>-</p>	<p>-</p> <p>+</p> <p>o</p>	No	<p><u>Effectiveness Factors:</u></p> <ol style="list-style-type: none"> 1. Better for treatment of halogenated VOCs. 2. No uncommon impacts to humans during action for any in-situ treatments. 3. Pilot-scale technology. 4. Clean up time – N/A. <p><u>Implementability Factors:</u></p> <ol style="list-style-type: none"> 1. Worse availability. 2. No treatment train required. 3. No residuals produced. 4. Worse system reliability and maintainability. <p><u>Cost Factors:</u></p> <ol style="list-style-type: none"> 1. Capital cost intensive. 2. Not O&M cost intensive.

Table 2.6-1 Evaluation of Retained Process Options for Subsurface Soil and Groundwater (cont.)

Process Option	Description	E	I	C	Retained	Evaluation Comments
						3. Average overall costs.
Oxidation	The target contaminant groups for oxidation are nonhalogenated VOCs and SVOCs, and fuel hydrocarbons, but specific chlorinated hydrocarbons that have been treated include TCE. Destruction of halogenated compounds requires special catalysts, special materials or construction, and the addition of a flue gas scrubber to reduce acid gas emissions.	o	o	+	Yes	<u>Effectiveness Factors:</u> 1. Better for treatment of halogenated VOCs, but better at high VOC concentrations. 2. No uncommon impacts to humans during action for any in-situ treatments. 3. Fully developed technology. 4. Clean up time – N/A.
	Influent gas concentrations must be < 25% of the lower explosive limit for catalytic and thermal oxidation.	+	+	+		<u>Implementability Factors:</u> 1. Better availability; special catalysts required. 2. No treatment train required. 3. No residuals produced. 4. Better system reliability and maintainability.
	The presence of chlorinated hydrocarbons may poison a particular catalyst. The primary factors that will impact the overall cost include quantity, concentration, and type of contaminant; required destruction efficiencies; management of residuals; and utility and fuel costs.	+	+	+		<u>Cost Factors:</u> 1. Not capital cost intensive. 2. Not O&M cost intensive. 3. Better overall costs.

Table 2.6-1 Evaluation of Retained Process Options for Subsurface Soil and Groundwater (cont.)

Key:

BTEX – benzene, toluene, ethylbenzene, and xylenes

COC – chemical of concern

DCE – dichloroethene

GAC – granulated activated carbon

GW – groundwater

IC – institutional control

ISCO – in-situ chemical oxidation

KMnO₄ – potassium permanganate

MCL – maximum contaminant level

N/A – not applicable

NAPL – non-aqueous-phase liquid

O&M – operation and maintenance

PCB – polychlorinated biphenyl

PCE – perchlorethylene, also known as tetrachlorethene

PCP – pentachlorophenol

PR-R1 – Priest Rapids-Roza 1

SVOC – semi-volatile organic compound

TBD – to be determined

TCE – trichloroethene

THP – Contaminants that can be treated include most or all VOCs and SVOCs. This technique is specifically useful for destroying organics and chlorinated solvents such as TCE. Both gas and liquid phase contaminants are treatable. This technology is best suited for treatment of gaseous streams with small concentrations of VOCs especially chlorinated compounds. Continued research and development is needed to better quantify treatment characteristics.

UV – ultra violet

VOC – volatile organic compound

ZVI – zero-valent iron

Table 3.1-1 Assembly Description (with Effectiveness, Implementability, and Cost Factors)

Components	Description	Targeted RAOs	Effectiveness Factors	Implementability Factors	Cost Factors
Assembly # 1 - Basic Actions					
1a - Institutional Controls	<p><u>Governmental</u> (such as State required well sampling for VOCs for new construction wells, testing of Group A wells, proposed well drilling State registration, etc.)</p> <p><u>Proprietary</u> (such as, easements and covenants)</p> <p><u>Enforcement Tools</u> – consent decrees, administrative orders</p> <p><u>Informational Tools</u> – local information distribution, etc.</p>	# 1	These controls are effective for meeting RAO 1 if carefully constructed and meaningfully enforced or acted upon.	Only implementable ICs are defined.	Costs vary but are usually manageable and reasonable for the level of protectiveness achieved through the IC. Costs include 5-year review, Restoration Advisory Boards, IC planning, implementation, training, follow-up, and quality control.
1b – Connection to water system or Alternate water supply via new well	<p>Connections to either City of Moses Lake or other local purveyor if within the Urban Growth Area.</p> <p>Else, new well, or if possible, connection to local water purveyor.</p> <p>There are an estimated five individual well users within each AOPC to which this action would apply. Five are within the Urban Growth Area (UGA); five are outside of the UGA.</p> <p>(See also table 3.1-3)</p>	# 1	These actions are effective for meeting RAO 1 (long-term solutions, to be combined with 1c.)	All actions are technically and administratively implementable at the site. However, connection to City of Moses Lake water is not administratively feasible for users outside of the UGA.	Costs include connections to (1) for five connections for water supply and sewer, or (2) five new wells, all with trenching/piping, site preparation and completion.
1c - Individual Well Treatment	Point-of-use activated carbon filters as a short-term action to prevent exposure to contaminated groundwater. This action includes the domestic well sampling program currently managed by U.S. Army Corps of Engineers.	# 1	These actions are effective for meeting RAO 1 (short-term solution)	This action is technically and administratively implementable at the site.	Capital costs include activated carbon filters for 10 wells users, domestic wells sampling, and program mgmt. O&M costs are for maintenance of carbon filters.

Table 3.1-1 Assembly Description (with Effectiveness, Implementability, and Cost Factors) (cont.)

Components	Description	Targeted RAOs	Effectiveness Factors	Implementability Factors	Cost Factors
1d – Long-Term Monitoring	Long-term monitoring will be used to support the above actions to ensure understanding of groundwater conditions, monitor changes, and to provide information on the performance of a remedial technology. The types of wells to be monitored consist of 35 new wells in PR-R1, 45 new wells in R2, divided between monitoring wells outside of the AOPCs (LTM wells), within the AOPCs (compliance wells), and wells (performance wells) within the AOPC treatment areas, if a remedial technology is selected (130 wells).	n/a	LTM is effective as support other actions.	These actions are technically and administratively implementable at the site.	Capital costs include monitoring for 128 wells for specific chemicals of concern and natural attenuation.
1e – Surface Barriers	Surface barriers (i.e., fencing) will be used to support ICs as needed.	n/a	Effective as a support for other actions.	Technically and administratively implementable site.	Capital costs include an estimated amount of fencing and accompanying signage.
Assembly # 2 – Containment					
Hydraulic Containment	This technology is not appropriate for the site. Capturing the shallow basalt aquifer would lead to increased vertical migration to Roza 2. Additionally, extracting clean water upgradient and re-injecting it downgradient is not practical at this site.	# 1 # 2	Not effective.	Not implementable	Costs are not an issue based on technology not being effective or implementable at the site.
Assembly # 3 – Groundwater Extraction and Treatment					
3a – Ex-situ treatment via carbon adsorption 3b – Ex-situ treatment via air stripping	<p>The assemblies for groundwater extraction and ex-situ treatment share the same number of extraction wells and flow rates for the respective AOPCs and depths of application (PR-R1 and R2). The difference between the two assemblies is the ex-situ treatment.</p> <p>1. Treatment for 2a is activated carbon. 2. Treatment for 2b is air stripping with vapor treatment.</p> <p>Each treatment method is equally effective for removing TCE from the groundwater. Groundwater is designed, at this point, to be extracted, treated, and returned to the alluvium via an infiltration gallery.</p>	# 1 # 2 # 3	<p>This action is targeted at meeting RAOs 1, 2, and 3 by reducing exposure to contaminated groundwater by attempting to meet RAOs 2 and 3.</p> <p>This action would reduce the mobility and/or volume of contamination in the treated areas. Other areas of concentration would attenuate over time.</p>	Implementability concerns for pumping and treating are the ability to maintain adequate mass removal to make the system worth running (diminishing returns) and infrastructure challenges with respect to piping to and from treatment area, to infiltration gallery, and locating and access to the treatment area.	Capital costs include costs for fencing, management, extraction wells, treatment method, trenching/ piping, utilities, storage tanks, infiltration gallery, and waste management. O&M costs are applied to wells, treatment method, infiltration gallery, and performance monitoring.

Table 3.1-1 Assembly Description (with Effectiveness, Implementability, and Cost Factors) (cont.)

Components	Description	Targeted RAOs	Effectiveness Factors	Implementability Factors	Cost Factors
Assembly # 4 – In-Situ Groundwater Treatment					
4a – In-situ treatment via potassium permanganate	The assemblies for in-situ treatment share the same number of extraction wells and flow rates for the respective AOPCs and depths of application. The difference between the two assemblies is the ex-situ treatment.	# 1	This action is targeted at meeting RAOs 1, 2, and 3 by reducing exposure to contaminated groundwater by attempting to meet RAOs 2 and 3.	Implementability concerns for either in-situ revolve around the potential for rebound in TCE concentrations some time after completion of application.	Capital costs include costs for fencing, management, injection wells, treatment agent, and waste management for a single event. O&M costs are applied to injection performance.
4b –In-situ treatment via nanoscale zero valent iron	1. Treatment for 4a is potassium permanganate (KMnO ₄). 2. Treatment for 4b is nanoscale zero valent iron.	# 2	This action would reduce the volume of concentration of contamination in the areas of highest concentration. Other areas of concentration would attenuate over time.		
	Each treatment method is equally effective for removing TCE from the groundwater.	# 3			

Effectiveness Factors: ability to meet desired RAO, and, for RAOs 2 – 4, the ability of the action to reduce the toxicity, mobility, or volume of contamination.

Implementability Factors: technical and administrative feasibility of constructing, reliably operate, and meet technology-specific regulations for process options throughout the remedial action.

Cost Factors: focus on comparative estimates for alternatives with relative accuracy; specifically, unit costs, vendor information, conventional cost-estimating guides, prior estimates, site-cost experience, and good engineering judgments; capital and O&M costs; present worth analysis.

Key:

AOPC – area of potential concern

IC – institutional control

LTM – long-term monitoring

O&M – operation and maintenance

PR-R1 – Priest Rapids-Roza 1

R2 – Roza 2

RAO – remedial action objective

TCE – trichloroethene

UGA – urban growth area

VOC – volatile organic compound

Table 3.1-2 Water-Supply Related Actions

Type of Well System	Sampling Strategy (Institutional Controls or Voluntary Sampling)	Action to be taken if Well Testing Shows TCE (or other COC) Above PRAG		
		Short-term Action(s)	Long-Term Action(s)	
			Well located within Urban Growth Area (UGA)	Well located outside UGA
Group A				
<u>Wells serving:</u> ≥15 residential connections, or ≥ 25 people per day for 60 or more days per year. Determination of contamination is made by the Grant County Health District. Ecology approves new well designs.	<u>New wells:</u> WAC 246-290-020 requires initial testing of wells to ensure water quality. This typically includes volatile organic compounds.	Wellhead treatment, such as activated carbon or air stripping.	Options: Connection to City of Moses Lake water or other water more closely located purveyor system, or a new well, depending which option is more effective, implementable, and cost-effective	No known Group A connections outside of UGA and within study area.
	<u>Existing wells:</u> Testing is required in WAC 246-290-300 when contamination is present or suspected in the water system.			
Group B				
<u>Wells serving:</u> < 15 residential connections, and < 25 people per day, or > 25 people per day for less than 60 days per year. Determination of contamination is made by the Grant County Health District. Ecology approves new well designs.	<u>New wells:</u> WAC 246-291 requires initial testing of a new water supply source. Usually, this does not include volatile organic compounds. However, testing is required in WAC 246-291-350 when contamination is present or suspected in the water system	Wellhead treatment, such as activated carbon or air stripping.	Options: Connection to City of Moses Lake water or other water more closely located purveyor system, or a new well, depending which option is more effective, implementable, and cost-effective	No known Group B connections outside of UGA and within study area.
	<u>Existing wells:</u> Testing is required in WAC 246-291-350 when contamination is present or suspected in the water system			
Individual Residential/Up to 4 Connections on a Single Farm				
<u>Wells serving:</u> single family residences or fewer than 5 residences on the same farm	<u>New and existing wells:</u> Voluntary sampling and IC Informational devices to encourage sampling	Point-of-use activated carbon filter.	Options: Connection to City of Moses Lake water or other water more closely located purveyor system, or a new well, depending which option is more effective, implementable, and cost-effective	New well
Other Wells				
Construction-related wells for residential or commercial activities. Determination of contamination is made by the Grant County Health District. Ecology approves new well designs.	<u>New wells:</u> Grant County Health District requires testing as part of permitting	Point-of-use activated carbon filter or well head treatment, such as activated carbon or air stripping, depending on size and type of distribution.	Options: Connection to City of Moses Lake water or other water more closely located purveyor system, or a new well, depending which option is more effective, implementable, and cost-effective	New well
	<u>Existing wells:</u> Voluntary sampling and IC Informational devices to encourage sampling			

Key:

TCE – trichloroethene COC – chemical of concern PRAG – preliminary remediation action goal UGA – urban growth area WAC – Washington Administrative Code

Table 3.2-1 Remedial Alternatives (cont.)

Alternative	Assemblies	Target RAOs	Retained for Detailed Analysis	E	I	C	Rationale for Retention/ General Comparison
AOPC 1 Priest Rapids-Roza 1 (PR-R1) aquifer							
I	No Action	0	Yes	O	O	O	Required under CERCLA
II	1 – Basic Action	1	Yes	O	+	+	Alternative prevents exposure (meets RAO #1), but does nothing to actively remediate groundwater. This alternative may be acceptable due to reducing risks and cost-effectiveness.
III	1 – Basic Action 3 – Ex-Situ Treatment	1, 2, 3	Yes	+	-	-	Alternative prevents exposure to contaminated groundwater (meets RAO #1) and attempts to reach RAOs 2 and 3 for groundwater remediation. Meeting RAO 2 is anticipated, but meeting RAO 3 is more uncertain, as the alternative does not directly treat source materials due to lack of knowledge of their exact locations. Alternative is more difficult to implement and less cost-effective than no action, but is more effective at reducing mobility, toxicity, and volume of contamination. Overall groundwater extraction and ex-situ treatment costs, at this time, seem to be an order of magnitude larger than in-situ treatment.
IV	1 – Basic Action 4 – In-Situ Treatment	1, 2, 3	Yes	+	-	-	Alternative prevents exposure to contaminated groundwater (meets RAO #1) and attempts to reach RAOs 2 and 3 for groundwater remediation. Meeting RAO 2 is anticipated, but meeting RAO 3 is more uncertain, as the alternative does not directly treat source materials due to lack of knowledge of their exact locations. Alternative is more difficult to implement and less cost-effective than no action, but is more effective at reducing mobility, toxicity, and volume of contamination. Overall in-situ treatment costs, at this time, seem to be in the same range of costs as Basic Action alone.
AOPC 1 - Roza 2 (R2) aquifer							
I	No Action	0	Yes	O	O	O	Required under CERCLA
II	1 – Basic Action	1	Yes	O	+	+	Same rationale as Alternative II for AOPC 1 PR-R1.
III	1 – Basic Action 3 – Ex-Situ Treatment	1, 2, 3	Yes	+	-	-	Same rationale as Alternative III for AOPC 1 PR-R1. Overall groundwater extraction and ex-situ treatment costs, at this time, seem to be two to six times larger than in-situ treatment costs.
IV	1 – Basic Action 4 – In-Situ Treatment	1, 2, 3	Yes	+	-	-	Same rationale as Alternative IV for AOPC 1 PR-R1. Overall in-situ treatment costs, at this time, seem to be in the same range of costs as Basic Action alone.

Table 3.2-1 Remedial Alternatives (cont.)

Alternative	Assemblies	Target RAOs	Retained for Detailed Analysis	E	I	C	Rationale for Retention/ General Comparison
AOPC 2 - Priest Rapids/ Roza 1 (PR-R1) aquifer							
I	No Action	0	Yes	O	O	O	Required under CERCLA
II	2 – Basic Action	1	Yes	O	+	+	Same rationale as Alternative II for AOPC 1 PR-R1.
III	1 – Basic Action 3 – Ex-Situ Treatment	1, 2, 3	Yes	+	-	-	Same rationale as Alternative III for AOPC 1 PR-R1. Overall groundwater extraction and ex-situ treatment costs, at this time, seem to be on the same order of magnitude as in-situ treatment costs.
IV	1 – Basic Action 4 – In-Situ Treatment	1, 2, 3	Yes	+	-	-	Same rationale as Alternative IV for AOPC 1 PR-R1. Overall in-situ treatment costs, at this time, seem to be three times greater than the costs of Basic Action alone.
AOPC 2 - Roza 2 (R2) aquifer							
I	No Action	0	Yes	O	O	O	Required under CERCLA
II	2 – Basic Action	1	Yes	O	+	+	Same rationale as Alternative II for AOPC 1 PR-R1.
III	1 – Basic Action 3 – Ex-Situ Treatment	1, 2, 3	Yes	+	-	-	Same rationale as Alternative III for AOPC 1 PR-R1. Overall groundwater extraction and ex-situ treatment costs, at this time, seem to be on the same order of magnitude as in-situ treatment costs.
IV	1 – Basic Action 4 – In-Situ Treatment	1, 2, 3	Yes	+	-	-	Same rationale as Alternative IV for AOPC 1 PR-R1. Overall in-situ treatment costs, at this time, seem to be 1.5 to three times greater than the costs of Basic Action alone.

Effectiveness Factors: ability to meet desired RAO, and, for RAOs 1-3

Implementability Factors: technical and administrative feasibility of constructing, reliably operate, and meet technology-specific regulations for process options throughout the remedial action.

Cost Factors: focus on comparative estimates for alternatives with relative accuracy; specifically, unit costs, vendor information, conventional cost-estimating guides, prior estimates, site-cost experience, and good engineering judgments; capital and O&M costs; present worth analysis.

See also table 3.1-1 for Assembly effectiveness, implementability, and cost factors.

AOPC – area of potential concern

CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act

O&M – operation and maintenance

RAO – remedial action objective

PR-R1 – Priest Rapids-Roza 1

Table 4.2-1 Remedial Alternatives (FS-level) Design Elements for Each AOPC

Design Components	AOPC 1 PR-R1	AOPC 1 R2	AOPC 2 PR-R1	AOPC 2 R2	Total
Alternative II – Basic Action					
Water and sewer connections (estimated, ea)	2	3	3	2	10
Individual well treatment units (estimated, ea)	2	3	3	2	10
Monitoring wells for long-term monitoring, compliance and performance (ea)	21	18	28	19	130
Area of AOPC reduced to (sq ft)	No change		No change		No change
Alternative III –Basic Action with Groundwater Extraction and Ex-Situ Treatment					
Hot-spot extraction wells (ea)	1	1	4, 2	3	11
Hot-spot injection wells (ea)	2	2	8, 4	6	18
Well spacing between extraction wells (ft)	-	-	675, 600	900	-
Distance from extraction wells (ft)	500	500	500, 500	500	-
Treatment units (in each treatment area, ea)	1	1	4, 2	3	11
Total extraction rate (gal per min)	90	30	960, 260	225	570
Volume of water treated (gal per day)	130,000	43,000	1.8 million	320,000	540,000
Volume of water treated (total over 30 yrs, gal)	1.4 billion	470 million	19 billion	3.5 billion	24 billion
TCE concentrations (avg over treatment area, µg/L)	40	25	40	25	-
TCE removed (total over 30 yrs, kg)	200	40	3,000	300	3500
Original area of AOPC (sq ft)	16,000,000		14,000,000		30 million
Area of AOPC reduced to (sq ft)	820,000		11,000,000		11.8 million
Alternative IV – Basic Action with In-Situ Groundwater Treatment					
TCE concentration (average over treatment area, µg/L)	80	25	80	25	-
Amount of reagent slurry (per injection, lbs)	2,250	1,125	10,000	5,000	18,400
Treatment applications (2 per yr for 30 yrs, ea)	60	60	60	60	240
Injection wells (per treatment area, ea)	13	13	36	36	98
Treatment line length (ft)	645	645	1,800	1,800	-
Treatment area (ft ²)	32,000	32,000	90,000	90,000	-
Volume of water treated (per injection, gal)	11 million	6.0 million	30 million	17 million	64 million
Volume of water treated (total over 30 yrs, gal)	660 million	360 million	1.8 billion	1.0 billion	3.8 billion
TCE treated (per injection, kg)	3	2	9	5	19
TCE treated (total over 30 yrs, kg)	200	100	500	300	1100
Original area of AOPC (sq ft)	16,000,000		14,000,000		30 million
Area of AOPC reduced to (sq ft)	110,000		4,600,000		4.61 million

Key:

AOPC – area of potential concern
ea – each
gal – gallons
kg – kilograms

sq ft – square feet
yrs – years
µg/L – micrograms per liter

Table 4.2-2 Alternative Evaluation and Comparison Against Seven CERCLA Criteria

Alternative	Overall Protection	Compliance with ARARs	Short-term Effectiveness	Long-term Effectiveness and Permanence	Reduction of Volume, Toxicity, and Mobility	Implementability	Cost (Present Value)	Sum
Overall Comparison between Alternatives (Ratings are shown in capital letters with points in parenthesis.)								
I – No Action – General for all Treatment Areas	FAIL. Does not protect human health.	FAILS. <u>Does not meet ARARs</u> , specifically, the PRAG.	POOR (1). Too long a period to consider.	POOR (1). Degrades existing protection program, high residual risk	POOR (1). No change over existing condition.	GOOD, GENERALLY FAVORABLE (3). Easy to implement, but implementation would entail cessation of current programs and 5-year reviews.	MOST FAVORABLE ALTERNATIVE (4) \$ 97,000	10
II – Basic Action Only – General for all Treatment Areas	FAIL. Achieves RAO 1 and protectiveness; does not affect the current extents of contamination	FAILS. <u>Does not meet ARARs</u> , specifically, the PRAG; does achieve protection by reducing exposure within identified areas.	FAIR, POTENTIALLY FAVORABLE (2). Immediate protection is achieved (RAO 1), but does not address reduction of plume (RAO 2).	POOR (1). Does not address source treatment (RAO 3)	POOR (1). Does not affect these factors.	FAIR, POTENTIALLY UNFAVORABLE (2). Uncertainty from reliance on local jurisdictions to agree and individuals' participation in protection programs.	GOOD, GENERALLY FAVORABLE (3) \$ 7,900,000	9
III – Extraction / Ex Situ Treatment – General for all Treatment Areas	PASS. Achieves RAOs 1 and 2; reduces extent of contamination through treatment.	FAILS. <u>Does not meet ARARs</u> , specifically, the PRAG. The PRAG value will continue to be exceeded in an area within AOPCs. However, these areas may be defined and circumscribed.	GOOD, GENERALLY FAVORABLE (3). Time to reach RAO 2 varies as shown under "Element," below. In conjunction with Basic Elements, provides short-term protectiveness.	FAIR, POTENTIALLY FAVORABLE (2). If applied overall, would reduce most but not all of the plume, leaving approximately 263 acres of untreated groundwater that would remain either until a source is encountered, or until it dissipates. Residual risks managed by incorporation of Alternative II (Basic Action). Disadvantage is that extraction/ex-situ treatment processes may operate for a very long time.	GOOD, GENERALLY FAVORABLE (3). If applied overall, would reduce 96% of AOPC 1 extent and 52% of AOPC 2 extent. See also Table 4.2-1 for design mass removals. (Note that these assume large sources.)	GOOD, GENERALLY FAVORABLE (3). Technology is well known; requires offsite shipment of wastes.	FAIR, POTENTIALLY UNFAVORABLE (2) \$ 19,000,000	13
IV In-Situ Treatment – General for all Treatment Areas	PASS. Achieves RAOs 1 and 2; reduces extent of contamination through treatment.	FAILS. <u>Does not meet ARARs</u> , specifically, the PRAG. The PRAG value will continue to be exceeded in an area within AOPCs. However, these areas may be defined and circumscribed. This alternative has an opportunity for source control, if source is identified.	GOOD, GENERALLY FAVORABLE (3). Time to reach RAO 2 varies as shown under "Element," below.	GOOD, GENERALLY FAVORABLE (3). Under some scenarios, receives a higher score. If applied overall, would reduce most but not all of the plume, leaving approximately 109 acres of untreated groundwater that would remain either until a source is encountered, or until it dissipates. Residual risks managed by incorporation of Alternative II (Basic Action). Advantage in that this technique can treat source(s) if encountered.	GOOD, GENERALLY FAVORABLE (3). Reduces area of AOPC 1 by 99% and AOPC 2 to 79%. Residual risks managed by incorporation of Alternative II (Basic Action).	FAIR, POTENTIALLY UNFAVORABLE (2) for most scenarios. May be GOOD, POTENTIALLY FAVORABLE under certain treatment scenarios (see below for assemblies/treatment areas). Technology is an extension of existing technologies, but applied in a way that is unusual (sources are typically controlled before application, or treated under application). In addition, the large number of injection wells may pose logistic problems.	POOREST (1) \$ 61,000,000 See assemblies, however	12

Table 4.2-2 Alternative Evaluation and Comparison Against Seven CERCLA Criteria (cont.)

Alternative	Overall Protection	Compliance with ARARs	Short-term Effectiveness	Long-term Effectiveness and Permanence	Reduction of Volume, Toxicity, and Mobility	Implementability	Cost (Present Value)	Sum
AOPC 1 PR-R1								
ALT III AOPC 1 PR-R1	See III Extraction / Ex Situ General	See III Extraction / Ex Situ General	GOOD, GENERALLY FAVORABLE (3). Meets RAO 2 in 9 years.	FAIR, POTENTIALLY FAVORABLE (2). Approximately 18.8 acres of plume would remain untreated. Probable long term for system operation.	GOOD, GENERALLY FAVORABLE (3). If applied to this area, would reduce contamination in 96% of AOPC 1 extent.	GOOD, GENERALLY FAVORABLE (3). Technology is well known; requires offsite shipment of wastes.	GOOD, GENERALLY FAVORABLE (3) \$ 1,800,000	14
ALT IV AOPC 1 PR-R1	See IV In-Situ General	See IV In-Situ General	GOOD, GENERALLY FAVORABLE (3). Meets RAO 2 in 10 years.	MOST FAVORABLE ALTERNATIVE (4). Leaves approximately 2.5 acres untreated. Although Alternative III appears to leave slightly less untreated area, the opportunity for treatment of a primary source gives this alternative an edge.	MOST FAVORABLE ALTERNATIVE (4). If applied to this area, would reduce contamination in 99% of AOPC 1 extent.	GOOD, GENERALLY FAVORABLE (3). Due to likelihood of a nearby limited source and "double duty" for assisting treatment of Roza 2, this scenario is favorable. (See text)	FAIR, POTENTIALLY UNFAVORABLE (2) \$ 6,300,000	16
AOPC 1 R2								
ALT III AOPC 1 R2	See III Extraction / Ex Situ General	See III Extraction / Ex Situ General	GOOD, GENERALLY FAVORABLE (3). Meets RAO 2 in 14 years.	FAIR, POTENTIALLY FAVORABLE (2). Approximately 18.8 acres of plume would remain untreated. Probable long term for system operation.	GOOD, GENERALLY FAVORABLE (3). If applied to this area, would reduce contamination in 96% of AOPC 1 extent	GOOD, GENERALLY FAVORABLE (3). Technology is well known; requires offsite shipment of wastes.	GOOD, GENERALLY FAVORABLE (3) \$ 2,000,000	14
ALT IV AOPC 1 R2	See IV In-Situ General	See IV In-Situ General	GOOD, GENERALLY FAVORABLE (3). Meets RAO 2 in 16 years.	FAIR, POTENTIALLY FAVORABLE (2). Leaves approximately 2.5 acres untreated. It is possible that separate application of Alternative IV AOPC1 PR-R1 would reduce TCE in this aquifer without direct intervention for treatment, since it could reduce the source.	MOST FAVORABLE ALTERNATIVE (4). If applied to this area, would reduce 99% of AOPC 1 extent	FAIR, POTENTIALLY UNFAVORABLE (2). Difficulties due to depth and injection of reagent, unusual application of technology create differences between this alternative and alternative III.	FAIR, POTENTIALLY UNFAVORABLE (2) \$ 3,400,000	13
AOPC 1 PR-R1 Main plume								
ALT III AOPC 2 PR-R1 (Main Plume)	See III Extraction / Ex Situ General	See III Extraction / Ex Situ General	MOST FAVORABLE (4). RAO 2 is already met in this area. However, treatment is still required to maintain RAO 2; the plume requires 3 years for the "wave" of clean water to propagate to the leading edge.	GOOD, GENERALLY FAVORABLE (3). Approximately 255 acres of plume would remain untreated. Probable long term for system operation.	GOOD, GENERALLY FAVORABLE (3). If applied to this area, would reduce 47% of this treatment area	GOOD, GENERALLY FAVORABLE (3). Technology is well known; requires offsite shipment of wastes.	GOOD, GENERALLY FAVORABLE (3) \$ 3,200,000	16
ALT IV AOPC 2 PR-R1 (Main Plume)	See IV In-Situ General	See IV In-Situ General	GOOD, GENERALLY FAVORABLE (3). RAO 2 is already met in this area. However, treatment is still required to maintain RAO 2; the plume requires 4 years for the "wave" of clean water to propagate to the leading edge.	GOOD, GENERALLY FAVORABLE (3). Reduces area of AOPC 2 to 106.3 acres.	GOOD, GENERALLY FAVORABLE (3). If applied to this area, would reduce contamination in 79% of AOPC 2 extent. This treatment scenario is not likely to treat a significant amount of source.	FAIR, POTENTIALLY UNFAVORABLE (2). Difficulties due to depth and injection of reagent, unusual application of technology create differences between this alternative and alternative III.	POOR (1) \$ 29,000,000	12
AOPC 1 PR-R1 NE plume								
ALT III AOPC 2 PR-R1 (NE Plume)	See III Extraction / Ex Situ General	See III Extraction / Ex Situ General	FAIR, POTENTIALLY FAVORABLE (2). Meets RAO 2 in 2.5 years; however, this area may not require treatment due to low levels of TCE and existing (and future) programs providing protection.	GOOD, GENERALLY FAVORABLE (3). Approximately 255 acres of plume would remain untreated. Probable long term for system operation.	FAIR, POTENTIALLY FAVORABLE (2). If applied, would reduce contamination in 87% of this treatment area	GOOD, GENERALLY FAVORABLE (3). Technology is well known; requires offsite shipment of wastes.	GOOD, GENERALLY FAVORABLE (3) \$ 2,000,000	13
ALT IV AOPC 2 PR-R1 (NE Plume) - Note a: The Northeast plume is not considered for this Alternative because this area is considered to be too near to residences to place reagents into the aquifers.								
AOPC 1 R2								
ALT III AOPC 2 R2 (Entire Plume)	See III Extraction / Ex Situ General	See III Extraction / Ex Situ General	FAIR, POTENTIALLY FAVORABLE (2). Meets RAO 2 in 7 years, almost twice as long as Alt IV.	GOOD, GENERALLY FAVORABLE (3). Approximately 255 acres of plume would remain untreated. Probable long term for system operation.	GOOD, GENERALLY FAVORABLE (3). If applied, would reduce contamination in 47% of this treatment area	GOOD, GENERALLY FAVORABLE (3). Technology is well known; requires offsite shipment of wastes.	GOOD, GENERALLY FAVORABLE (3) \$ 2,100,000	13
ALT IV AOPC 2 R2	See IV In-Situ General	See IV In-Situ General	GOOD, GENERALLY FAVORABLE (3). Meets RAO 2 in 4 years.	GOOD, GENERALLY FAVORABLE (3). Reduces area of AOPC 2 to 106.3 acres.	GOOD, GENERALLY FAVORABLE (3). If applied to this area, would reduce contamination in 79% of AOPC 2 extent. This treatment scenario is not likely to treat a significant amount of source.	FAIR, POTENTIALLY UNFAVORABLE (2). Difficulties due to depth and injection of reagent, unusual application of technology create differences between this alternative and alternative III.	POOR (1) \$ 14,000,000	11

AOPC – area of potential concern CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act NE – Northeast
ARAR – applicable or relevant and appropriate requirements PR-R1 – Priest Rapids-Roza 1 R2 – Roza 2 RAO – remedial action objective

Table 4.2-3 Alternative Cost Analysis

Application Area	Alternative	Total Capital ¹ Costs	Total Periodic ² Costs	Total O&M ³ Costs	Total Costs ⁴	Total Present Value at 7.0% ⁵
All	I No Action	\$ -	\$ 220,000	\$ -	\$ 220,000	\$ 97,000
All	II Basic Action Only	\$ 4,900,000	\$ 180,000	\$ 11,000,000	\$ 16,000,000	\$ 7,900,000
AOPC 1 – PR-R1	Assembly 3					
	Groundwater Extraction and Ex-Situ Treatment	\$ 940,000	\$ -	\$ 2,000,000	\$ 2,800,000	\$ 1,800,000
	Assembly 4					
AOPC 1 – R2	In-Situ Groundwater Treatment	\$ 850,000	\$ -	\$ 13,000,000	\$ 14,000,000	\$ 6,300,000
	Assembly 3					
	Groundwater Extraction and Ex-Situ Treatment	\$ 1,200,000	\$ -	\$ 1,900,000	\$ 3,100,000	\$ 2,000,000
AOPC 2 – PR-R1 – Main plume	Assembly 4					
	In-Situ Groundwater Treatment	\$ 700,000	\$ -	\$ 6,700,000	\$ 7,400,000	\$ 3,400,000
	Assembly 3					
AOPC 2 – PR-R1 – NE plume	Groundwater Extraction and Ex-Situ Treatment	\$ 1,700,000	\$ -	\$ 3,400,000	\$ 5,100,000	\$ 3,200,000
	Assembly 4					
	In-Situ Groundwater Treatment	\$ 4,900,000	\$ -	\$ 60,000,000	\$ 65,000,000	\$ 29,000,000
AOPC 2 – R2	Assembly 3					
	Groundwater Extraction and Ex-Situ Treatment	\$ 1,000,000	\$ -	\$ 2,400,000	\$ 3,400,000	\$ 2,000,000
	Assembly 4					
AOPC 2 – R2	In-Situ Groundwater Treatment	No comparable cost				
	Assembly 3					
	Groundwater Extraction and Ex-Situ Treatment	\$ 1,300,000	\$ -	\$ 1,900,000	\$ 3,100,000	\$ 2,100,000
AOPC 2 – R2	Assembly 4					
	In-Situ Groundwater Treatment	\$ 2,100,000	\$ -	\$ 30,000,000	\$ 32,000,000	\$ 14,000,000

Notes:

1. Includes costs for design, bench and pilot testing (if necessary), equipment/chemical costs, construction and implementation, and institutional controls.
2. Includes costs for groundwater monitoring, and reporting (when necessary), electricity (when necessary), and periodic parts (when necessary).
3. Includes costs for five-year reviews and closure reporting.
4. Total Capital Costs + Total Periodic Costs + Total O&M Costs = Total Project Cost.

AOPC – area of potential concern

NE – Northeast

PR-R1 – Priest Rapids-Roza 1

R2 – Roza 2

Table 4.2-4 Potential Institutional Controls/Land Use Controls ^a (cont.)

IC Type	IC	Mechanism	Goals	Timing	Responsibility and Partnering Opportunity (WAC or RCW Reference)
<p><u>Washington Administrative Code (WAC)</u>—Regulations of executive branch agencies are issued by authority of statutes. Like legislation and the Constitution, regulations are a source of primary law in Washington State. The WAC codifies the regulations and arranges them by subject or agency. The Revised Code of Washington (RCW) is the compilation of all permanent laws now in force. It is a collection of Session Laws (enacted by the Legislature, and signed by the Governor, or enacted via the initiative process), arranged by topic, with amendments added and repealed laws removed. It does not include temporary laws such as appropriations acts.</p>					
Governmental Controls					
Local Permits	Municipal Water Law: Interim Planning Guidance for Water System Plan/ Small Water System Management Program Approvals: DOH PUB. #331-256	Purveyors must gain approval for a water system plan from Washington State Department of Health (WDOH).	Water Quality	These requirements will remain in effect until DOH establishes long-term processes that will be phased in over the next three years.	This requires coordination with the Division of Environmental Health: Office of Drinking Water, to enforce, monitor and upward reporting.
Local Permits	RCW 18.104	In order to protect the public health, welfare, and safety of the people it is necessary that provision be made for the regulation and licensing of well contractors and operators and for the regulation of well design and construction.	Water Quality	Water Well construction is regulated by the state before any action can take place.	The legislature declares that the drilling, making, or constructing of wells within the state is a business and activity of vital interest to the public. Opportunity to increase awareness while partnering with the interests of the state.
	Water Well construction				
Local Permits	WAC 173-200	Through the issuance of state waste discharge permits, other departmental permits, regulatory orders, court actions, review, and approval of plans and specifications water quality standards are maintained.	Water Quality	These standards are also enforced with the state's technological-based treatment requirements.	The department shall pursue memoranda of understanding with other state agencies to develop policies and rules that will require all known, available, and reasonable methods of prevention, control, and treatment to achieve compliance. Enforcement limits shall be defined on a case-by-case basis and shall be met at the point of compliance as defined in WAC 173-200-060.
	Water Quality Standards for Ground Waters of the State of Washington				
Financial Assistance	WAC 173-98 Uses and Limitations of the Water Pollution Control Revolving Fund	This fund provides financial assistance to applicants throughout the state of Washington who need such assistance to meet high priority water quality management needs. Homeowners in zones of contamination could apply for this funding.	Water Quality	The process begins with site-specific planning, and continues through design to construction or implementation.	The purpose of this chapter is to set forth limitations on the allocation and uses of moneys administered by the department of ecology from a special fund within the state treasury known as the state water pollution control revolving fund (SRF), as authorized by chapter 90.50A RCW.
Zoning Guidelines	WAC 173-100	Establishes guidelines, criteria, and procedures for the designation of ground water management areas, subareas, or zones. This chapter is promulgated by the department of ecology pursuant to RCW 90.44.400-90.44.440.	Water Resource Management	Activities to be supported with data collection efforts, hydrogeology studies, water quality studies, water use studies, land use studies, and population projections.	The intent of this chapter is to forge a partnership between a diversity of local, state, tribal and federal interests. Requires coordinating with advisory committee meetings; presenting draft materials to the committee for review, responding to comments from the committee; coordinating SEPA review; executing inter-local agreements or other contracts; and other duties as may be necessary.
	Ground Water Management Areas and Programs				

Table 4.2-4 Potential Institutional Controls/Land Use Controls ^a (cont.)

IC Type	IC	Mechanism	Goals	Timing	Responsibility and Partnering Opportunity (WAC or RCW Reference)
Groundwater Sampling Program	WAC 173-340	The Model Toxics Control Act (MTCA) establishes administrative processes and standards to identify, investigate, and clean up locations where hazardous materials have been located.	Hazardous Waste and Toxics Reduction	Once ground water clean-up levels have been established at the site, the ground water must be sampled to demonstrate compliance with clean up levels. Several locations are sampled for at least a year, and often several years.	Under WAC 173-340-360 and a consent decree or issue, an order for cleanup action for all designated high priority sites within six months of the completion of the RI/FS.
	Model Toxics Control Act- Cleanup				
Groundwater Monitoring Controls	WAC 246-290	Purveyors shall be responsible for complying with the regulatory requirements. Can be coupled with the capacity requirement for water systems mandated in the federal Safe Drinking Water Act.	Water Quality	Requires adequate design, construction, sampling, and management, maintenance, and operation practices for public water supply systems.	Requires coordination with DOH and upward reporting. Could be coupled with the guide for small non-expanding community Group A water Systems: DOH PUB #331-134.
	DOH: Public Water Supplies				
Groundwater Use Restriction, Monitoring, Zoning and Fees	WAC 246-291	Establishes fees for the review and approval of water system plans, project reports, construction documents, existing systems and related evaluations	Water Quality	Costs are defined in WAC language according to project type for Group A community members. At cost to the homeowner.	Includes satellite management agencies (SMAs) which means an individual, purveyor, or entity that is approved by the secretary to own or operate more than one public water system on a regional or county-wide basis, without the necessity for a physical connection between such systems.
	WAC 246-293				
	WAC 246-294				
	WAC 246-295				
	DOH: Water Systems				
Groundwater: Bacteriological Sampling Program	Grant Public Health: Water Program Fees	Establishes fees for review, evaluation, and system approval for sampling program at no cost to the home owner.	Water Quality Monitoring	Costs are defined according to Group designation and service needed. This includes Group A as well.	Partner with Grant County. Opportunity to prevent further exposure by coupling efforts and educating the public.
Groundwater use restriction	WAC 332-41-665	Policies and procedures for conditioning or denying permits or other approvals related to drilling, as well as pre-drilling sampling efforts and notification of drilling.	Well Drilling	To use in overlay zones that seek permits for future plans for well expansion.	Coordination with the Department of Natural Resources efforts related to geothermal drilling and SEPA regulations to mitigate specific adverse environmental impacts.
	SEPA Policies and Procedures				

Table 4.2-4 Potential Institutional Controls/Land Use Controls ^a (cont.)

IC Type	IC	Mechanism	Goals	Timing	Responsibility and Partnering Opportunity (WAC or RCW Reference)
Groundwater use restriction	WAC 173-154	Establishes policies and procedures to protect the occurrence and availability of ground water within the upper aquifers or upper aquifer zones where there are multiple aquifer systems.	Water Resources	To restrict future aquifer acquisition in overlay zones.	In enforcement of this chapter, the department of ecology may impose such sanctions as are appropriate under authorities vested in it, including but not limited to the issuance of regulatory orders under RCW 43.27A.190 and civil penalties under RCW 90.03.600.
	Protection of upper aquifer zones				
Groundwater use restriction	WAC 173-152	Establishes need for investigations with applications for new water right applications or transfer of existing water rights.	Water Quality Monitoring	For immediate efforts to monitor water, use in overlay zones and manage future water acquisition.	Department of Ecology consults with the public, federal, state, tribal, local jurisdictions and interested parties.
	Water Rights				
Condemnation of property	RCW 8.08.010	Every county is authorized and empowered to condemn land and property within the county for public use.	Land Use	Depends on Board of County Commissioners protocol and county procedures.	Responsibility of the courts, judge, and board of commissioners to determine best practices for condemnation.
	Eminent Domain				
Covenants	RCW 79.36	The department is authorized to property or the use of such roads by gift, purchase, exchange, or condemnation, and subject to all of the terms and conditions of such gift, purchase, exchange, or decree of condemnation.	Land Use	To coordinate efforts to access zones of contamination with department's land management road system.	Need to coordinate with Department of Natural Resources.
	Restrictive easements over Public Lands				
Consent Decrees	RCW 43.21A.440	Department authorized to participate in and administer federal Comprehensive Environmental Response, Compensation, and Liability Act.	Implementing ROD Documents on publicly held lands	Not Applicable	The Department of Ecology is authorized to participate fully as contemplated for state participation and administration under the RCW for CERCLA
	CERCLA Policies				
Educational Programs	WAC 173-173	Homeowner can be informed about water quality issues while required to report about water source withdrawal activity.	Water Quality Education	Can be in conjunction with existing reporting requirements.	RCW 90.44.450 directs the Dept. of Ecology to require that information about the water being withdrawn be reported to the department.
	Requirements for Measuring and Reporting Water Use				

Table 4.2-4 Potential Institutional Controls/Land Use Controls ^a (cont.)

IC Type	IC	Mechanism	Goals	Timing	Responsibility and Partnering Opportunity (WAC or RCW Reference)
Educational Programs	WAC 173-100	Groundwater user groups already adhere to procedures to identify probable water management areas.	Water Quality Education	Can be in conjunction with existing program.	Use existing partnership between local, state, tribal and federal interests to educate about quality of water.
	Ground Water Management Areas and Programs				
Deed Notices	RCW 65.12.005	The homeowner of any estate or interest in land applies to have the title of their land registered.	Legal Descriptions, Property definitions	Information can be presented when homeowner applies for land title and ascertain the efforts on neighboring properties.	Legal descriptions can contain information about water source contamination that could remain available for all future homeowners. If there is a need to establish boundary lines, the names and post office addresses of all the owners of the adjoining lands that may be affected thereby, as far as he is able, upon diligent inquiry, to ascertain the same.
	Registration of Land Titles				
Advisories	WAC 173-160	These regulations are adopted under chapter <u>18.104</u> RCW, to establish minimum standards for the construction and decommissioning of all wells in the state of Washington.	Well Drilling	On construction of new well.	The issuance of regulatory orders under RCW 43.27A.190; Civil penalties under RCW 90.03.600 and 18.104.155; and Criminal penalties under RCW 18.104.160.
	Construction and maintenance of wells				
Advisories	WAC 173-162	These regulations are adopted under chapter <u>18.104</u> RCW in order to establish procedures for the examination, licensing, and regulation of well contractors and operators.	Well Drilling	See cell to right.	Application fees are twenty-five dollars for each operator or training license. Licenses issued under this chapter, except a training license, shall be renewed every two years.
	Regulation and licensing of water well contractors and operators				

^a These are not all ARARs, but are design components.

CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act

DOH – Department of Health

IC – institutional control

MTCA – Model Toxics Control Act

RCW – Revised Code of Washington

RI/FS – remedial investigation/feasibility study

ROD – Record of Decision

SEPA – State Environmental Protection Administration

SMA – satellite management agency

SRF – state revolving fund

WAC – Washington Administrative Code

GROUNDWATER FEASIBILITY STUDY

FIGURES

Moses Lake Wellfield Contamination

Superfund Site

Moses Lake, Washington

April 2007



**US Army Corps
of Engineers®**
Seattle District

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- 1.3-2 Current Water Service Map
- 1.4-1 Site Vicinity Map and Potential Source Areas
- 1.4-2 Generalized Stratigraphy
- 1.4-3 Location of Cross Sections
- 1.4-4 Geologic Cross Section A-A'
- 1.4-5 Geologic Cross Section B-B'
- 1.4-6 Geologic Cross Section C-C'
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- 1.5-3 Preliminary Areas of Potential Concern
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1.5-8 Roza 2 Aquifer TCE Concentrations

1.6-1 Identification of Possible Plumes in Roza I and Priest Rapids Aquifers in Remedial Investigation

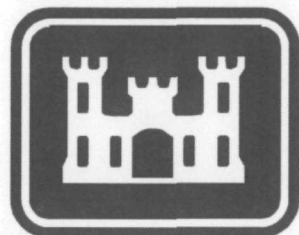
2.2-1 AOPC and Detected TCE Related to Zoning Categories

3.1-1 Diagrammatic Representation of Extraction Well Arrays

4.2-1 Remedial Alternatives

4.2-2 Alternative III Well Locations and Objective State

4.2-3 Alternative IV Well Locations and Objective State



**US Army Corps
of Engineers**

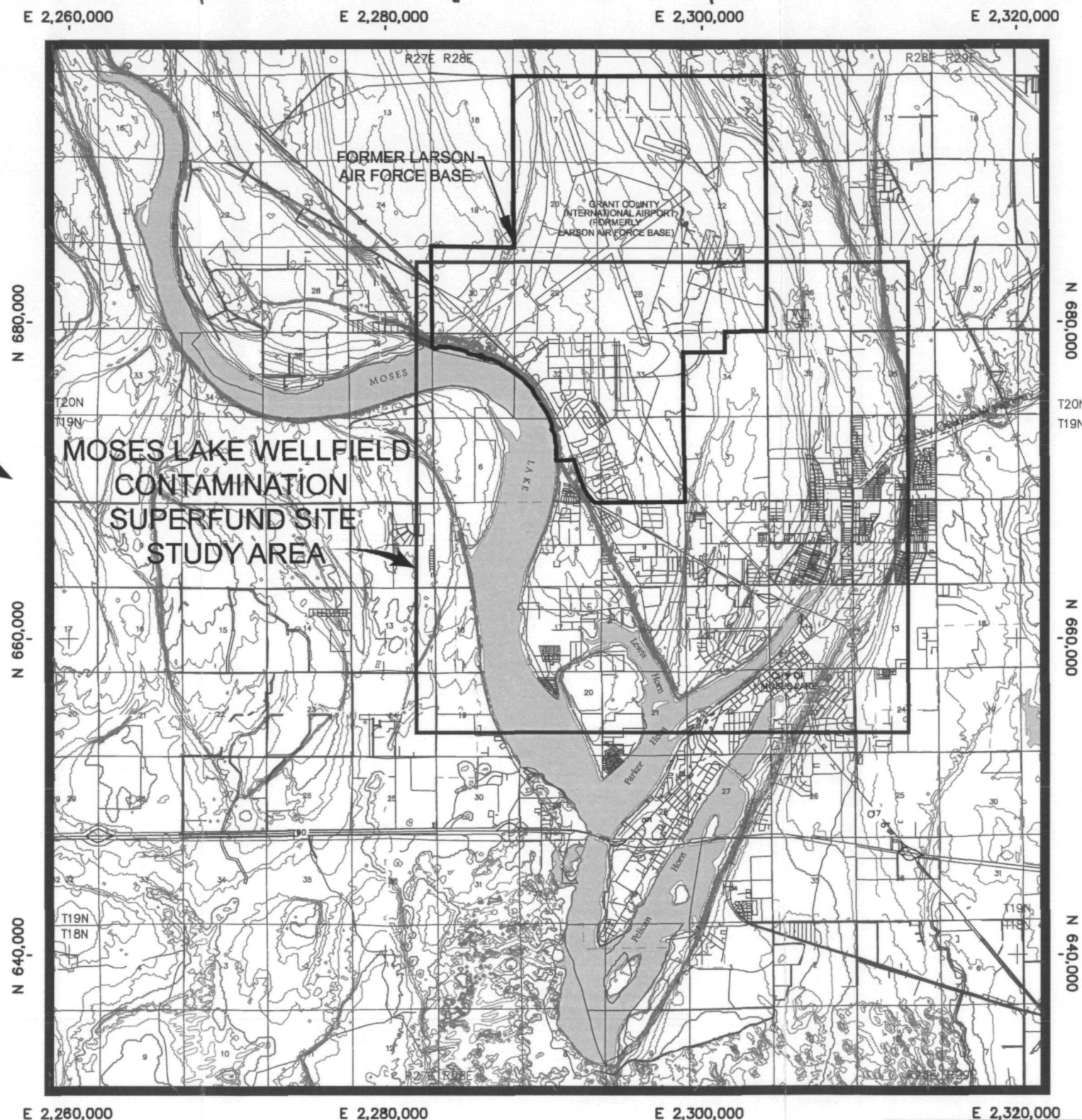
Seattle District



WASHINGTON

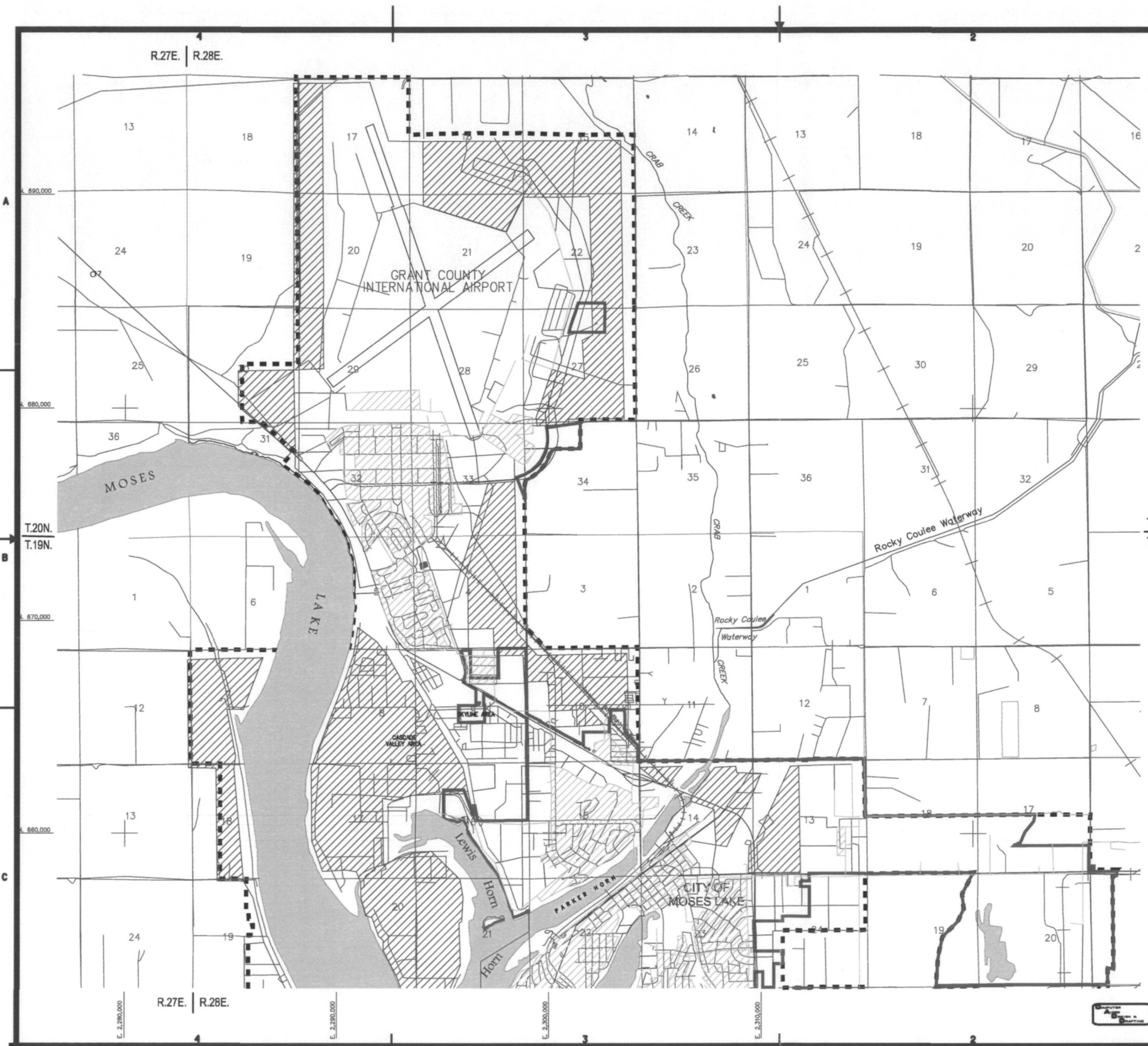
Site Vicinity

Fig.	Title
1.0-1	Site Vicinity and Location Map with Drawing Index
1.2-1	2003 Grant County Zoning Map
1.3-1	Existing and Future Northern City of Moses Lake Water Service Areas
1.3-2	Current Water Service Map
1.4-1	Site Vicinity Map and Potential Source Areas
1.4-2	Generalized Stratigraphy
1.4-3	Location of Cross-sections
1.4-4	Geologic Cross-section A-A'
1.4-5	Geologic Cross-section B-B'
1.4-6	Geologic Cross-section C-C'
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1.4-8	Priest Rapids Isopach Map
1.4-9	Alluvial Aquifer Potentiometric Surface Map
1.4-10	Priest Rapids-Roza 1 Aquifer Potentiometric Surface Map
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1.5-2	Conceptual Site Model for Physical Fate and Transport
1.5-3	Preliminary Areas of Potential Concern
1.5-4	TCE Distribution along Cross-Section A-A'
1.5-5	TCE Distribution along Cross-Section B-B'
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1.5-7	TCE Distribution along Cross-Section D-D'
1.5-8	Roza 2 Aquifer TCE Concentrations
1.6-1	Identification of Possible Plumes in Roza 1 and Priest Rapids Aquifers in Remedial Investigation
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2.2-1	AOPC and Detected TCE Related to Zoning Categories
3.1-1	Diagrammatic Representation of Extraction Well Arrays
4.2-1	Remedial Alternatives
4.2-2	Alternative III Well Locations and Objective State
4.2-3	Alternative IV Well Locations and Objective State



MOSES LAKE WELLFIELD CONTAMINATION SUPERFUND SITE

U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS		
SEATTLE, WASHINGTON		
MOSES LAKE WELLFIELD SUPERFUND SITE GROUNDWATER FEASIBILITY STUDY		
SITE VICINITY AND LOCATION MAP WITH DRAWING INDEX		
MOSES LAKE WASHINGTON		
DATE	FILE NO.	FIGURE NO.
MAR 05		1.0-1
TECH SWANSON	CHK. WAKEMAN	SHEET



LEGEND

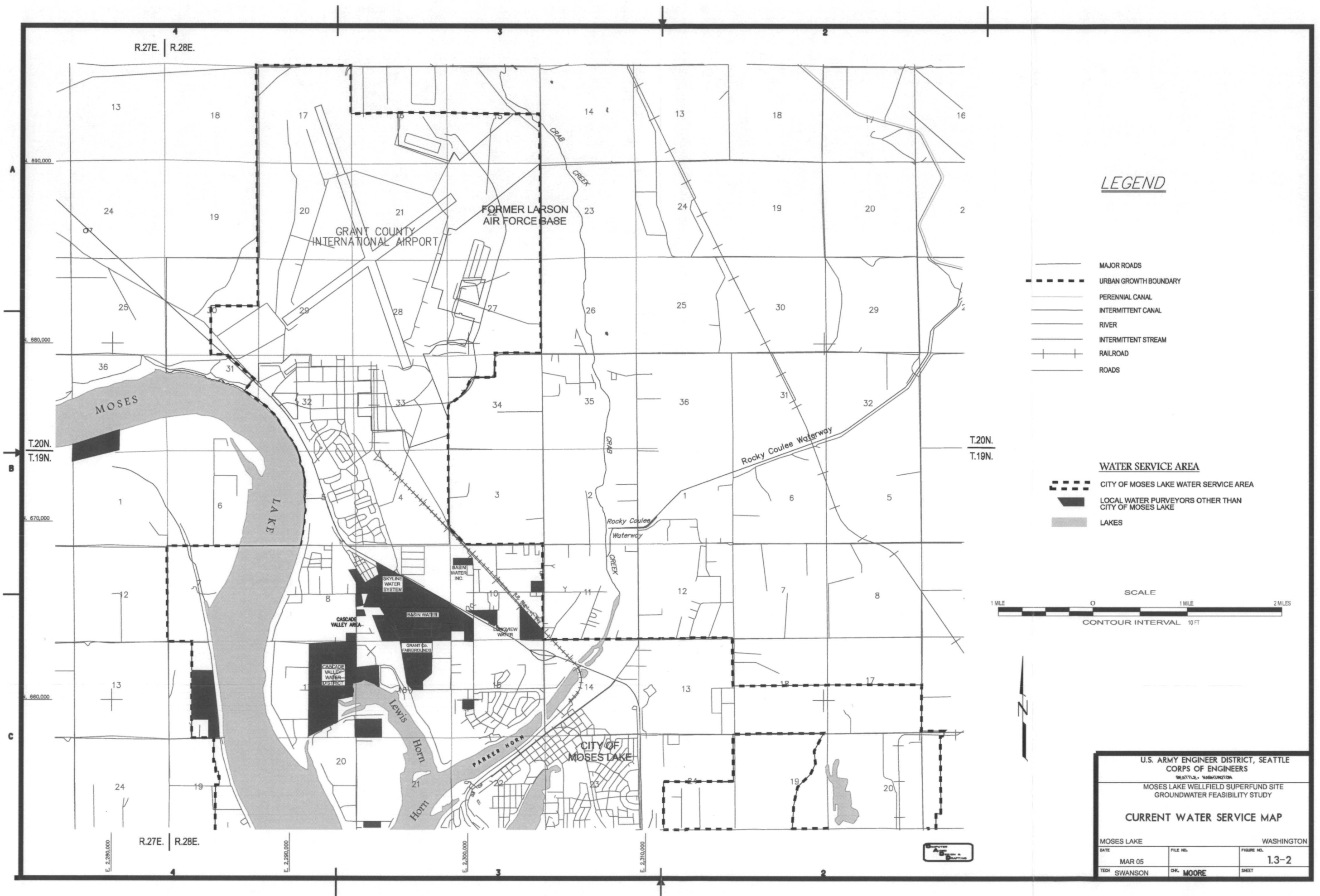
- MAJOR ROADS
- CITY OF MOSES LAKE
- URBAN GROWTH BOUNDARY
- PERENNIAL CANAL
- INTERMITTENT CANAL
- RIVER
- INTERMITTENT STREAM
- RAILROAD
- ROADS

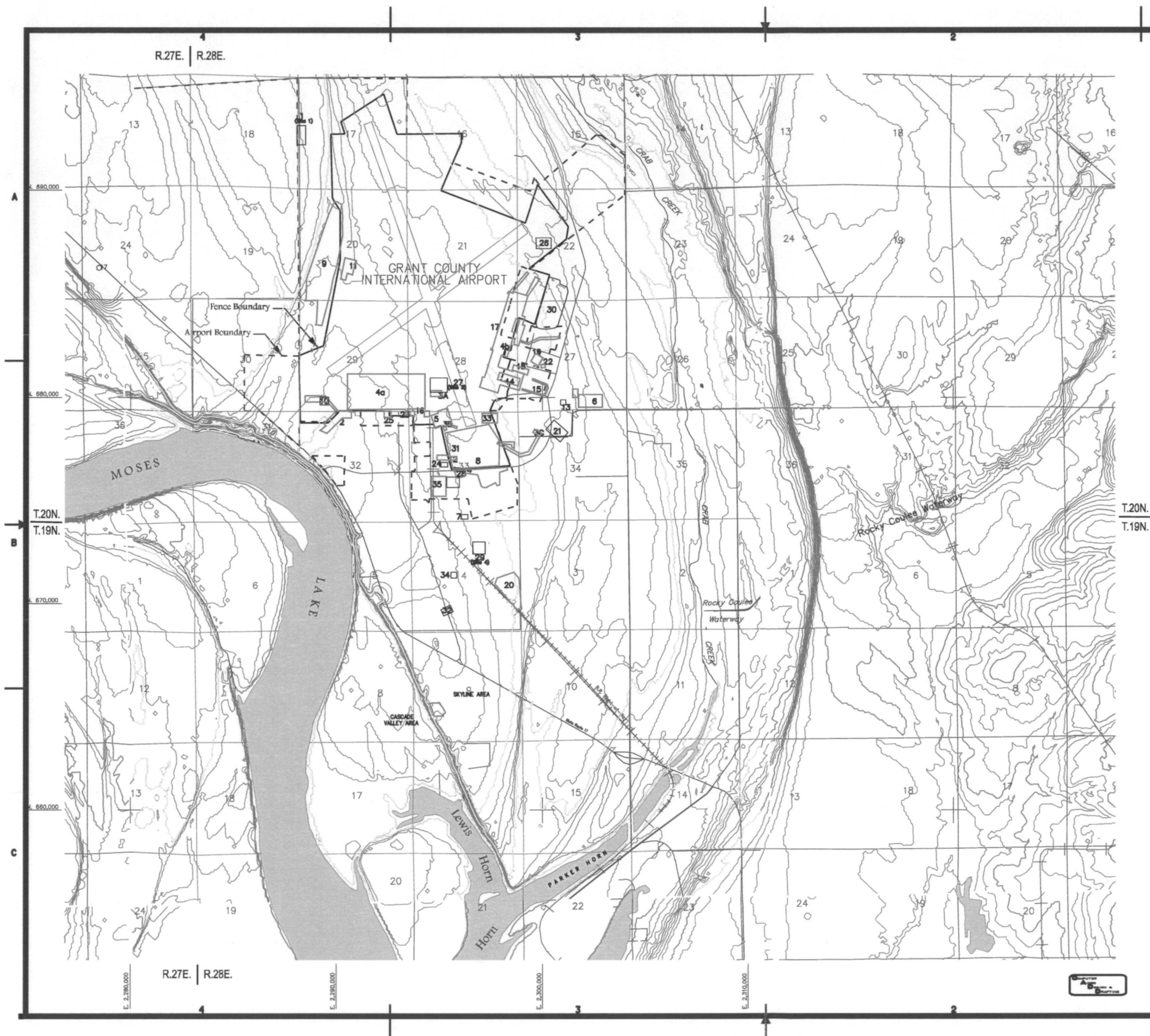
WATER SYSTEM DIAGRAM

- WATER SERVICE AREA
- EXISTING SERVICE ZONES
- FUTURE SERVICES & IMPROVEMENT AREAS



U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON		
MOSES LAKE WELDFIELD SUPERFUND SITE GROUNDWATER FEASIBILITY STUDY		
EXISTING & FUTURE NORTHERN CITY OF MOSES LAKE WATER SERVICE AREAS		
MOSES LAKE	WASHINGTON	
DATE MAR 05	FILE NO.	FIGURE NO. 1.3-1
TECH SWANSON	CHK MOORE	SHEET





LEGEND

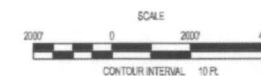
- MAJOR ROADS
- 12** POTENTIAL SOURCE AREA

2002 POTENTIAL SOURCE AREAS

- | | |
|---|--|
| 1 LIQUID WASTE DISPOSAL SITE | 19 LIQUID OXYGEN GENERATING PLANT (Bldg. 5102) |
| 2 BIG BEND COMMUNITY COLLEGE HANGAR | 19b ALTERNATE LOX DISPOSAL SITE |
| 3 AIRCRAFT WASH RACK (2a) & DISCHARGE AREAS (2b & 3c) | 20 SOUTH BASE DUMP |
| 4a TARMAC AREA A | 21 LARSON MUNICIPAL WASTE TREATMENT PLANT |
| 4b TARMAC AREA B | 22 PAINT HANGAR LEACH PIT |
| 5 JAL HANGAR AREA & TARMAC | 23 ENGINE BUILDUP FACILITY (Bldg. 2113) |
| 6a BASE CLOSURE LANDFILL | 24 BUILDING 2802 |
| 6b DUMPSTER WASH AREA | 25 BUILDING 408 |
| 7 ROCK LANDFILL | 26 CONVENTIONAL AMMUNITION STORAGE BUNKERS |
| 8 RANDOLPH ROAD BASE DUMP | 27 TETRAETHYL LEAD DISPOSAL SITE |
| 9 GRAVEL PIT | 28 TETRAETHYL LEAD DISPOSAL SITE |
| 10 FIRE TRAINING AREA BURN PIT A | 29 LOW-LEVEL RADIOACTIVE MEDICAL WASTE DISPOSAL SITE |
| 11 FIRE TRAINING AREA BURN PIT B | 30 BUNKER DISPOSAL AREA |
| 12 MOTOR POOL DRAIN | 31 19th AVENUE BASE DUMP |
| 13 ROCK DRAIN AREA | 32 SOUTH BURN PIT |
| 14 8-PLACE HANGAR | 33 DUMP AT THE END OF RUNWAY 32 |
| 15 8-PLACE HANGAR DITCH | 34 PATTON PARK LANDFILL |
| 16 ENGINE REBUILDING FACILITY (Bldg. 2203) | 35 STAINED SOIL AREA |
| 17 3-PLACE HANGAR (Bldg. 5801) | 36 SKYLINE AUTO WRECKING YARD |
| 18 PAINT HANGAR (Bldg. 5825) | |

NOTE:

SITE LOCATION AND POTENTIAL SOURCE AREA INFORMATION FROM "REMEDIAL INVESTIGATION & BASELINE RISK ASSESSMENT REPORT," 2003, MWH.

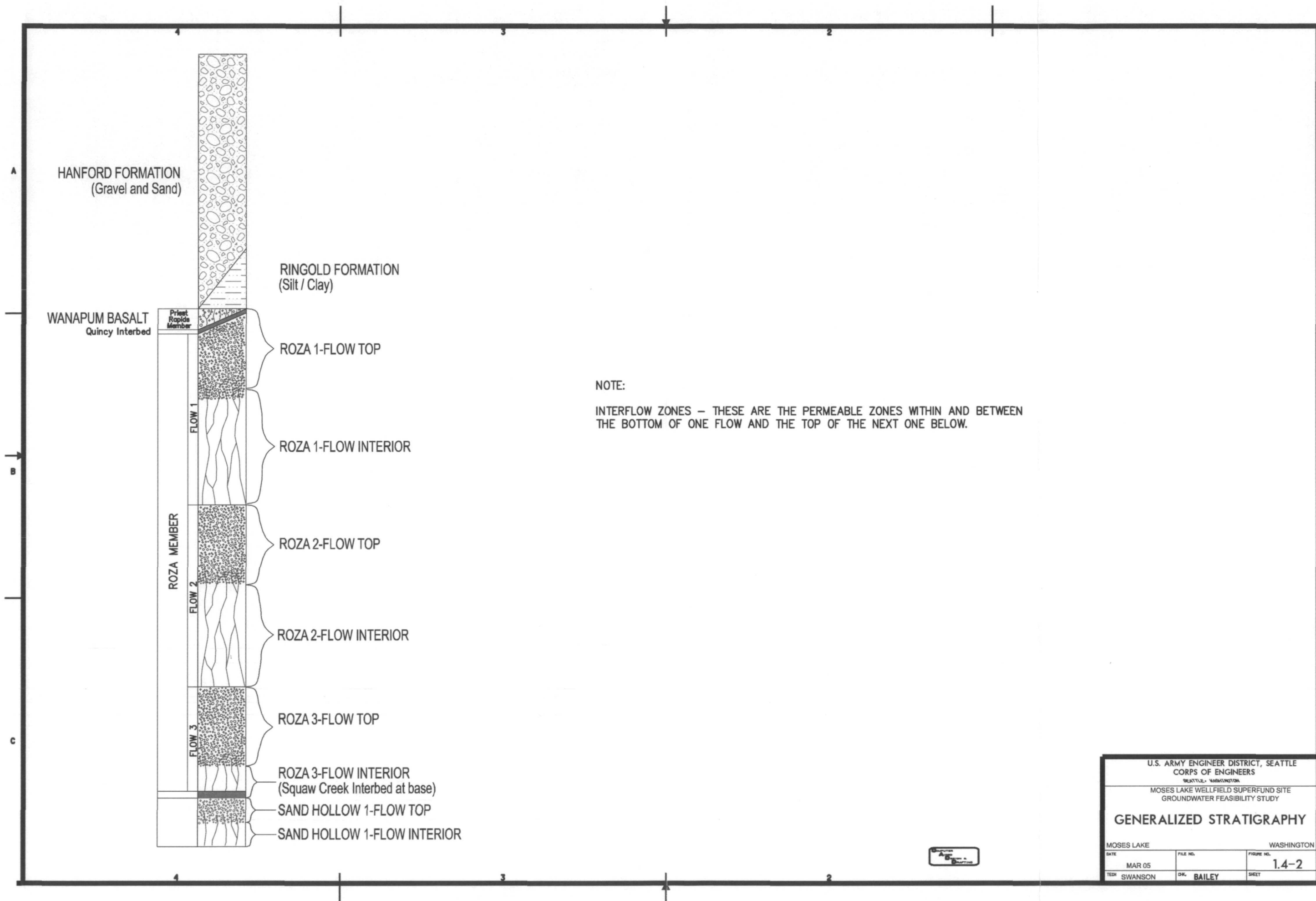


U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS

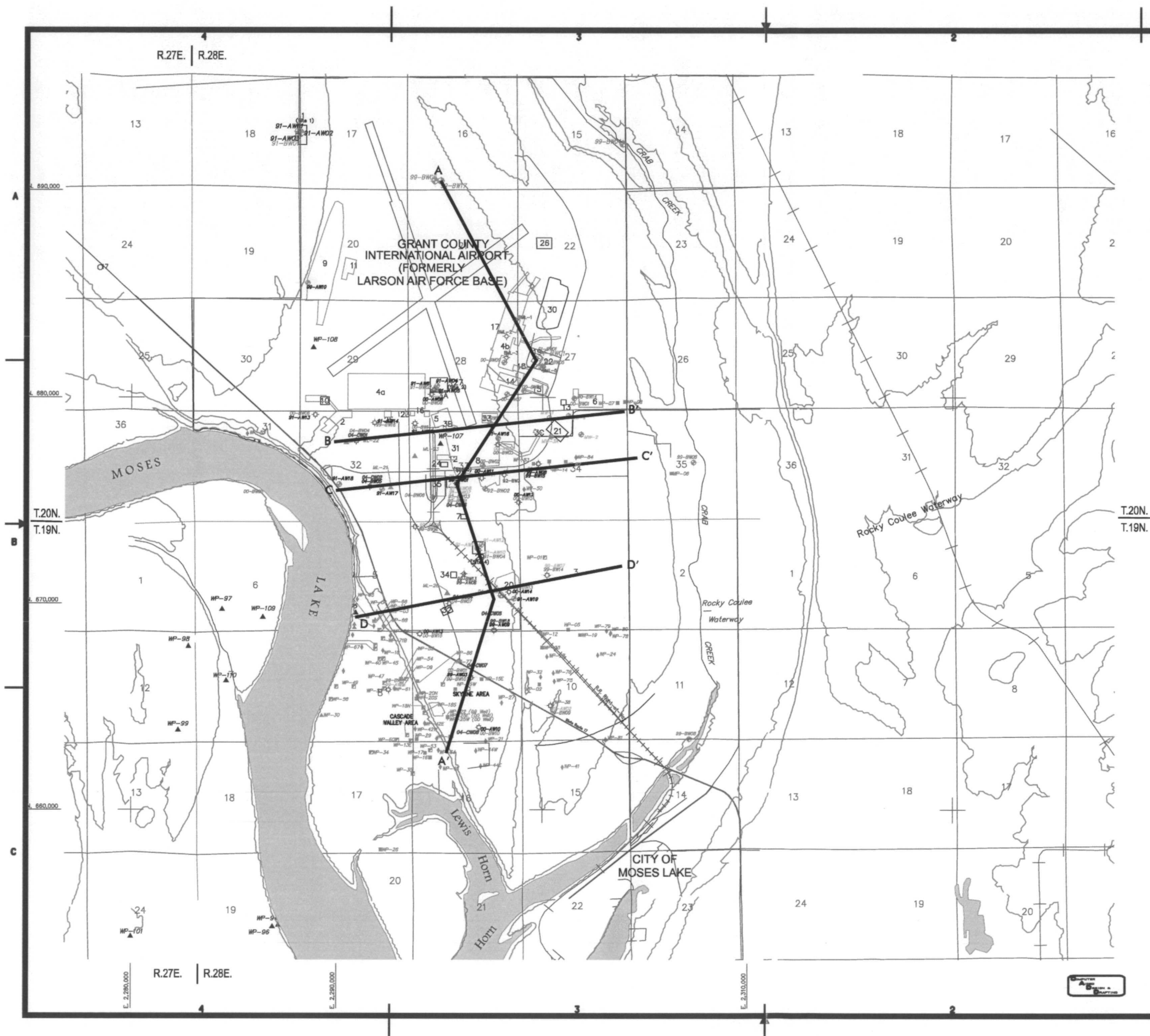
SEATTLE, WASHINGTON
MOSES LAKE WELLFIELD SUPERFUND SITE
GROUNDWATER FEASIBILITY STUDY

SITE VICINITY MAP AND POTENTIAL SOURCE AREAS

MOSES LAKE		WASHINGTON	
DATE	FILE NO.	FIGURE NO.	
MAR 05		1.4-1	
TECH SWANSON	CHK. GARRISON	SHEET	



U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON		
MOSES LAKE WELLFIELD SUPERFUND SITE GROUNDWATER FEASIBILITY STUDY		
GENERALIZED STRATIGRAPHY		
MOSES LAKE	WASHINGTON	
DATE MAR 05	FILE NO.	FIGURE NO. 1.4-2
TECH SWANSON	CHK. BAILEY	SHEET



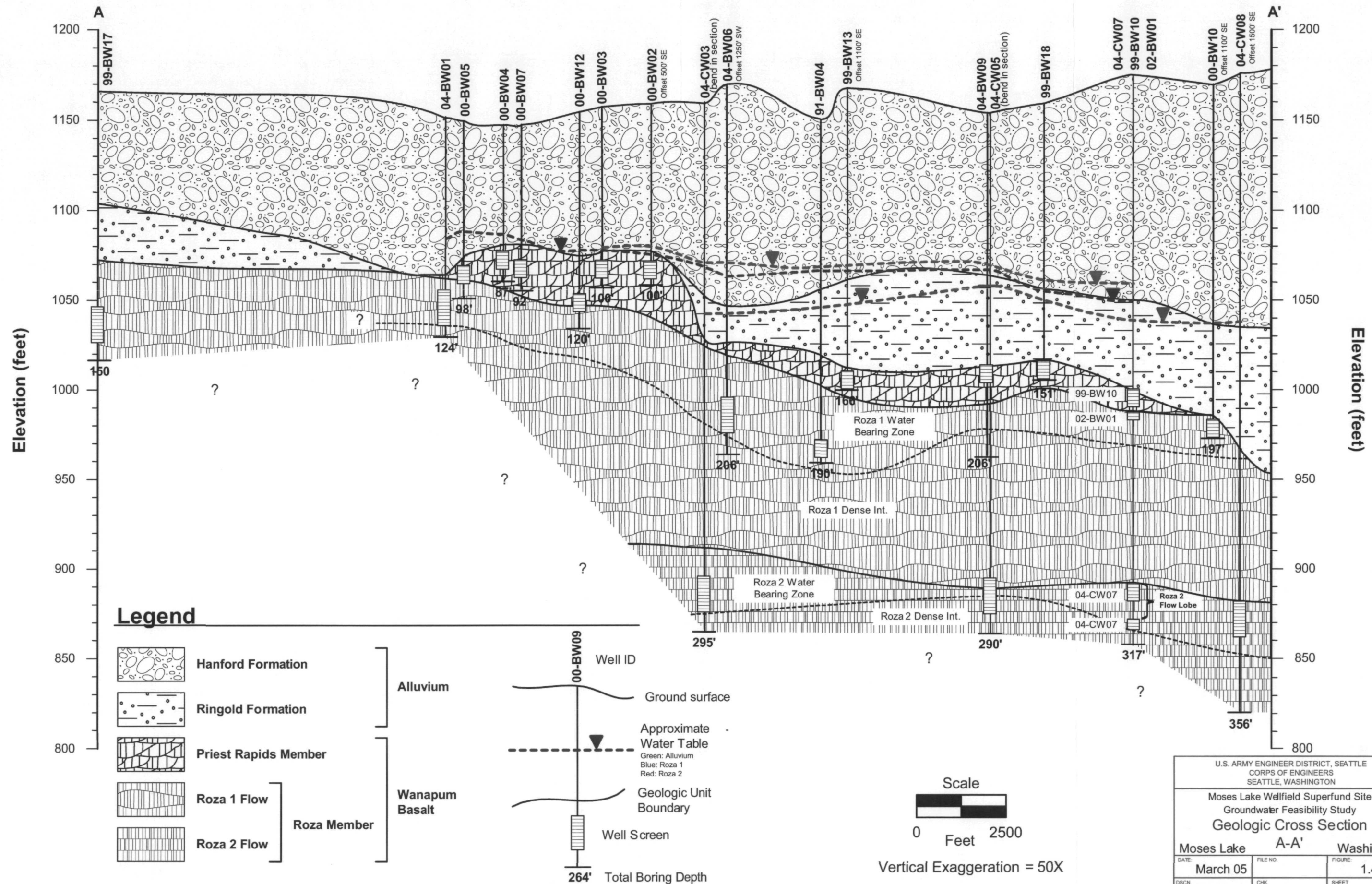
LEGEND

- ⊕ LOCATION OF GROUPED WELLS
- or ▲ or ⊙ LOCATION OF SINGLE WELL

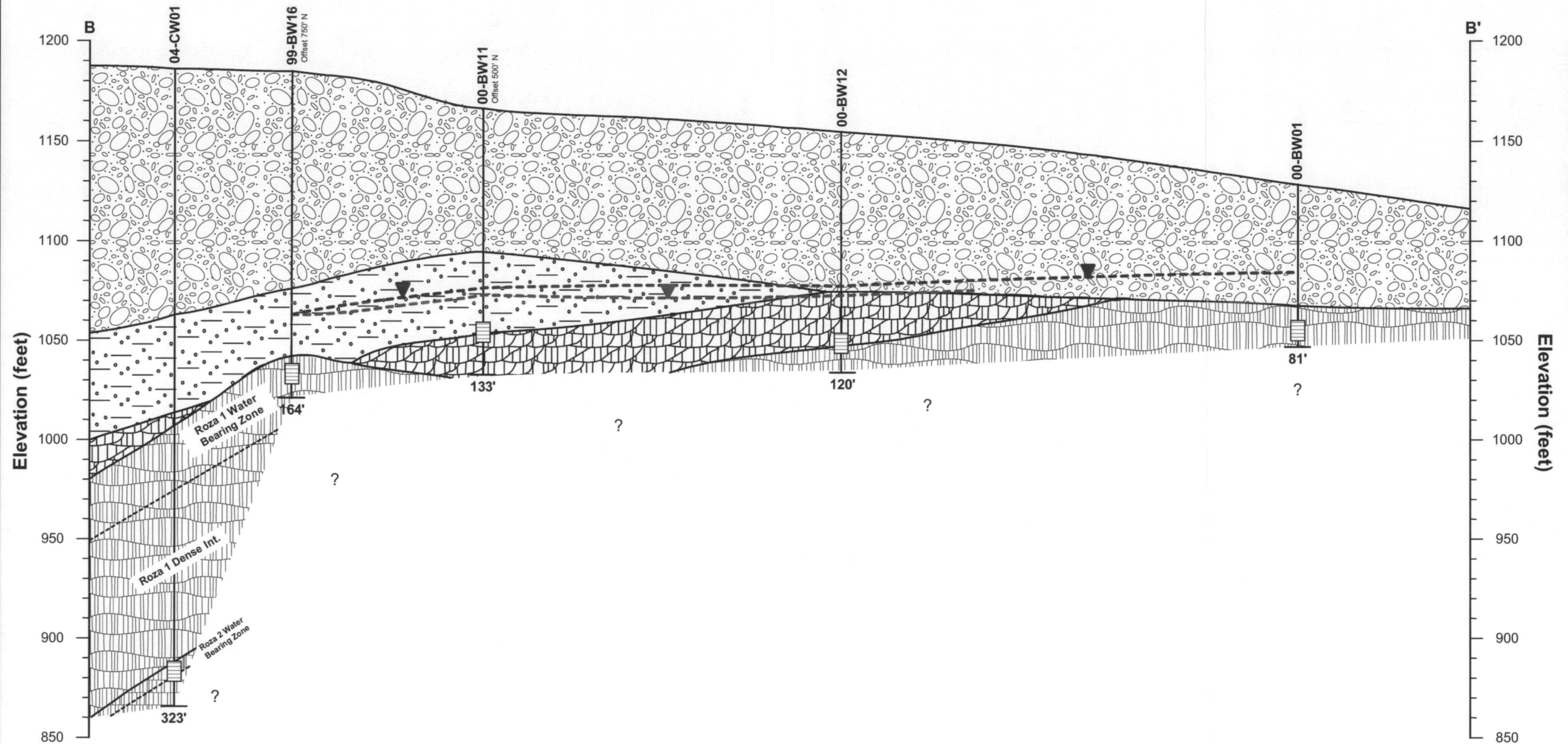
NOTES:

1. GEOLOGICAL CROSS-SECTIONS ARE SHOWN ON FIGURES 1.4-4 THRU 1.4-7.
2. TCE CROSS-SECTIONS ARE SHOWN ON FIGURES 1.5-4 THRU 1.5-7.

U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON		
MOSES LAKE WELLFIELD SUPERFUND SITE GROUNDWATER FEASIBILITY STUDY		
CROSS SECTION LOCATIONS		
MOSES LAKE		WASHINGTON
DATE MAR 05	FILE NO.	FIGURE NO. 1.4-3
TECH SWANSON	CHK. GARRISON	SHEET

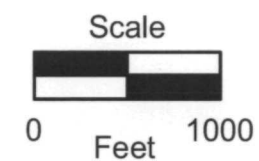


U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON		
Moses Lake Wellfield Superfund Site Groundwater Feasibility Study Geologic Cross Section A-A'		
Moses Lake	Washington	
DATE March 05	FILE NO.	FIGURE 1.4-4
DSCN EBNET	CHK.	SHEET



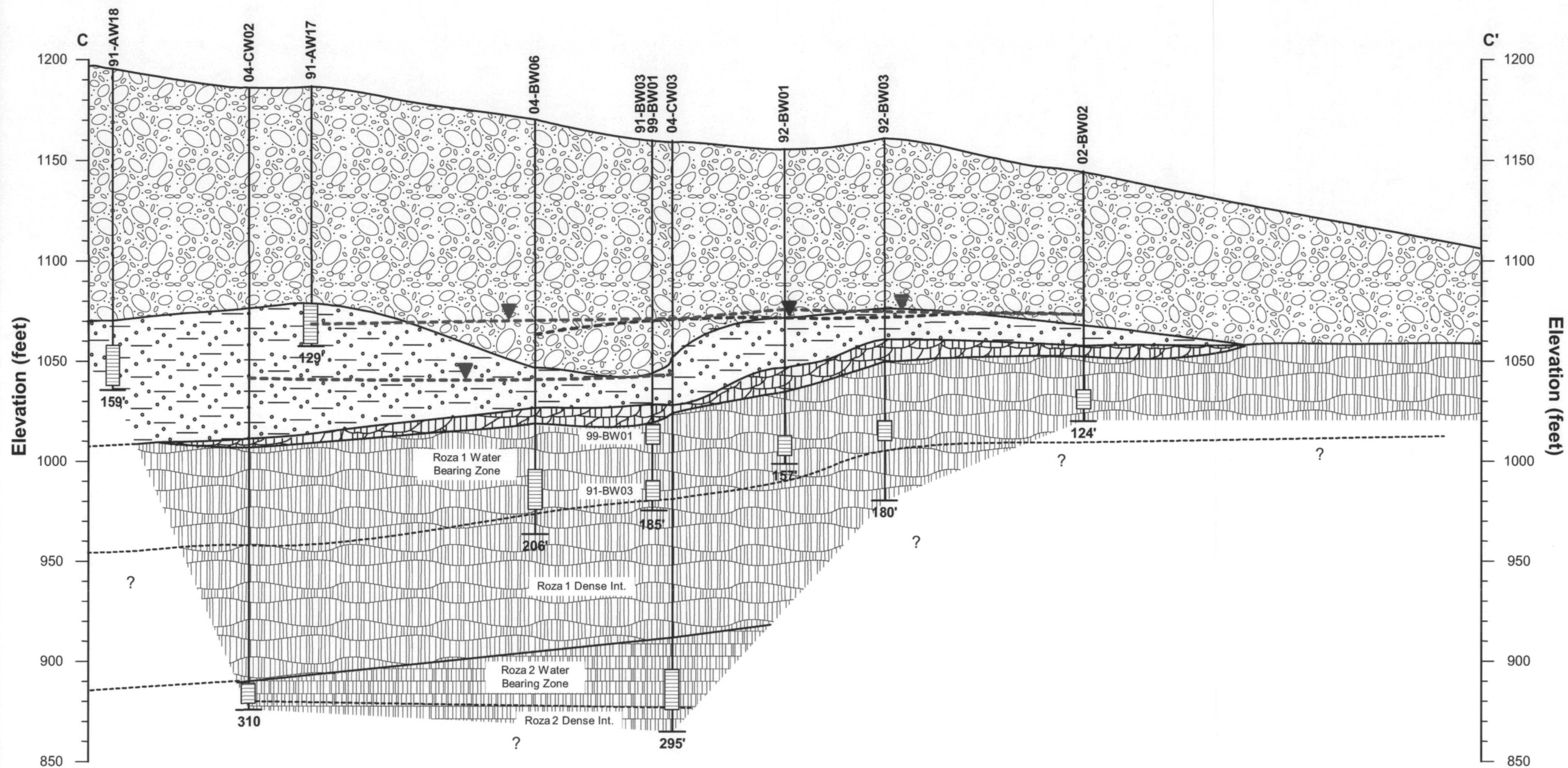
Legend

see Figure 1.4-4



Vertical Exaggeration = 20X

U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON		
Moses Lake Wellfield Superfund Site Groundwater Feasibility Study Geologic Cross Section B-B'		
Moses Lake	Washington	
DATE March 05	FILE NO.	FIGURE 1.4-5
DSCR EBNET	CHK.	SHEET



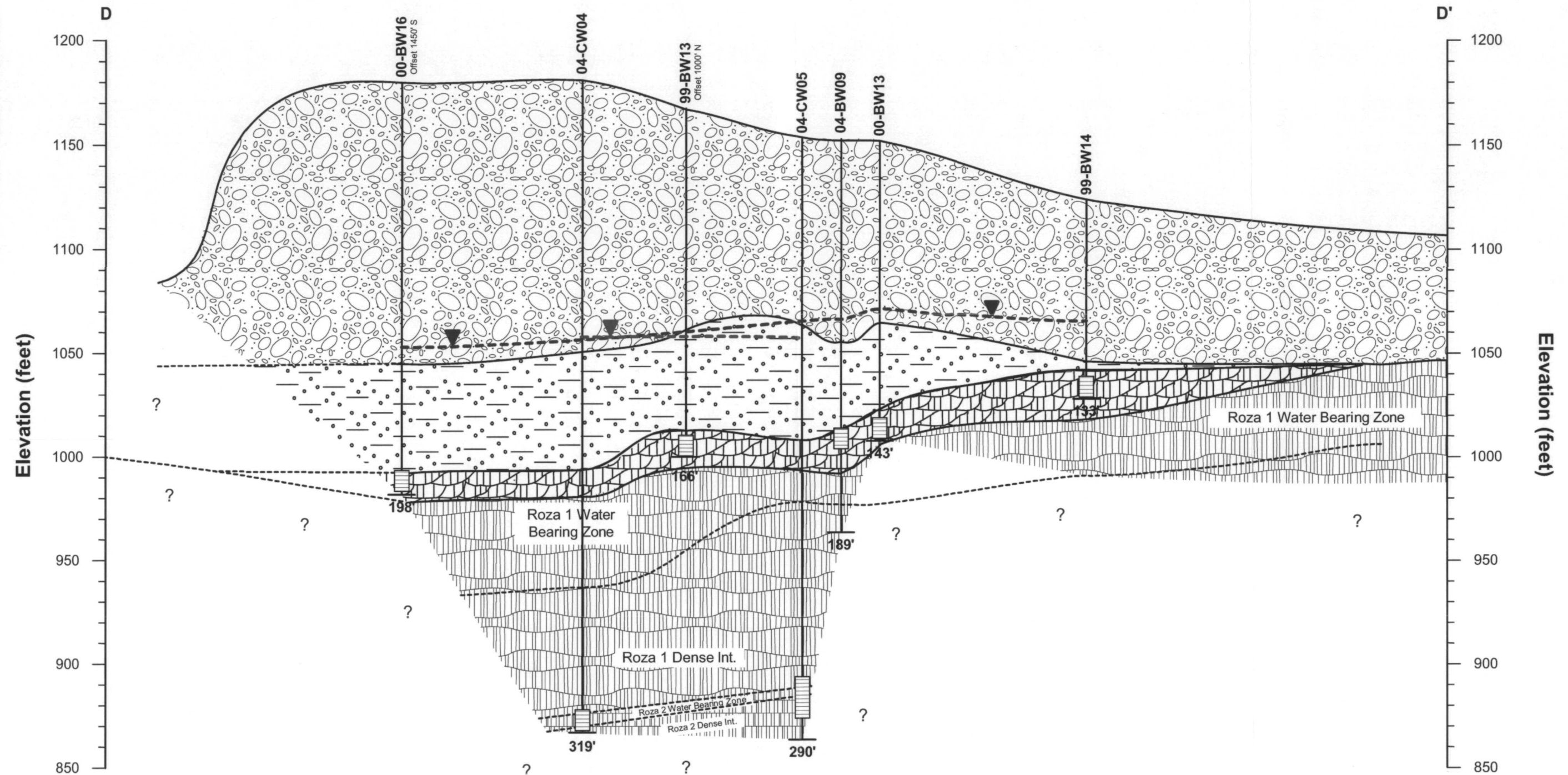
Legend

see Figure 1.4-4



Vertical Exaggeration = 20X

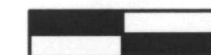
U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON		
Moses Lake Wellfield Superfund Site Groundwater Feasibility Study Geologic Cross Section		
Moses Lake	C-C'	Washington
DATE March 05	FILE NO.	FIGURE 1.4-6
DSCN EBNET	CHK.	SHEET



Legend

see Figure 1.4-4

Scale



0 Feet 1000

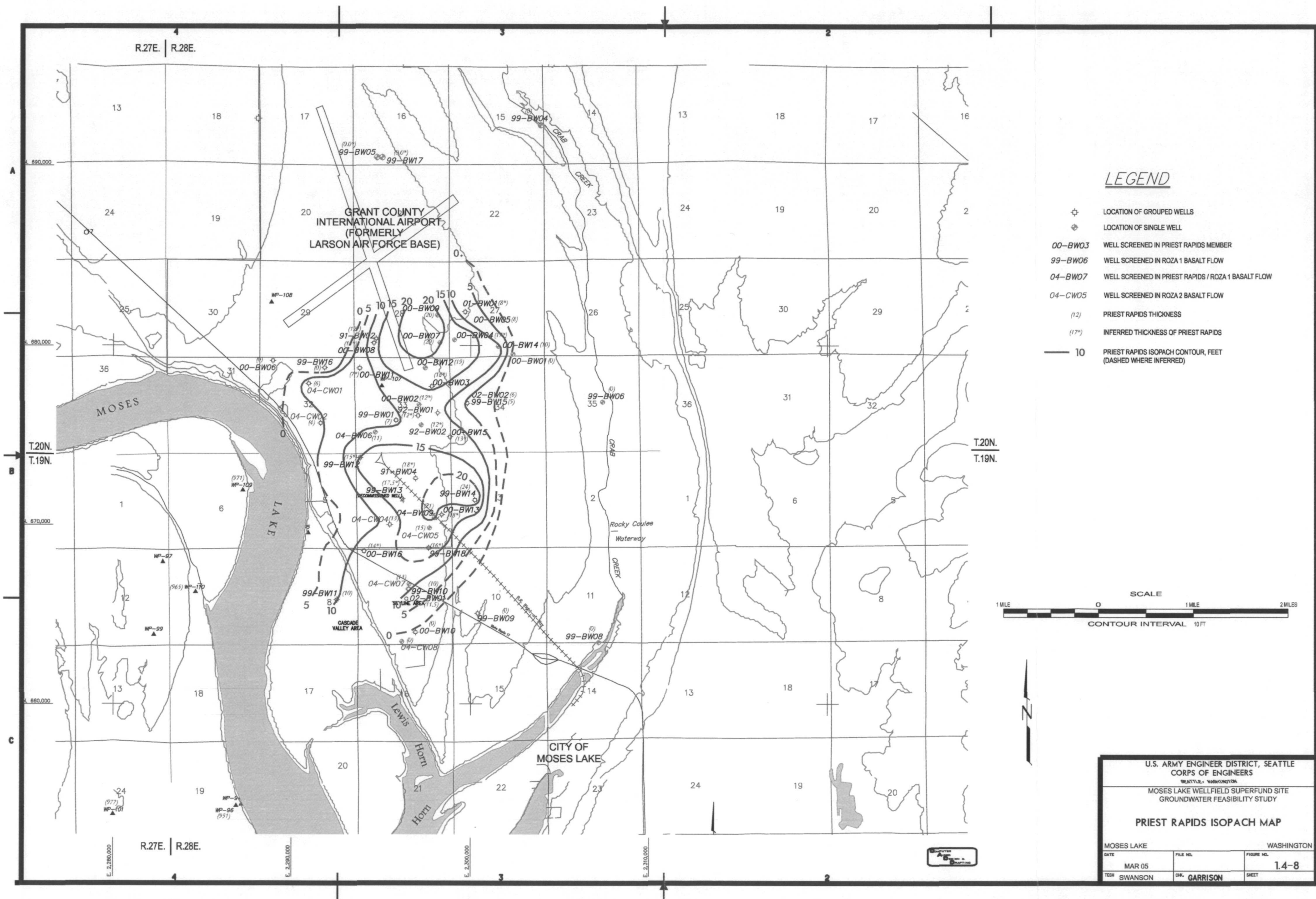
Vertical Exaggeration = 20X

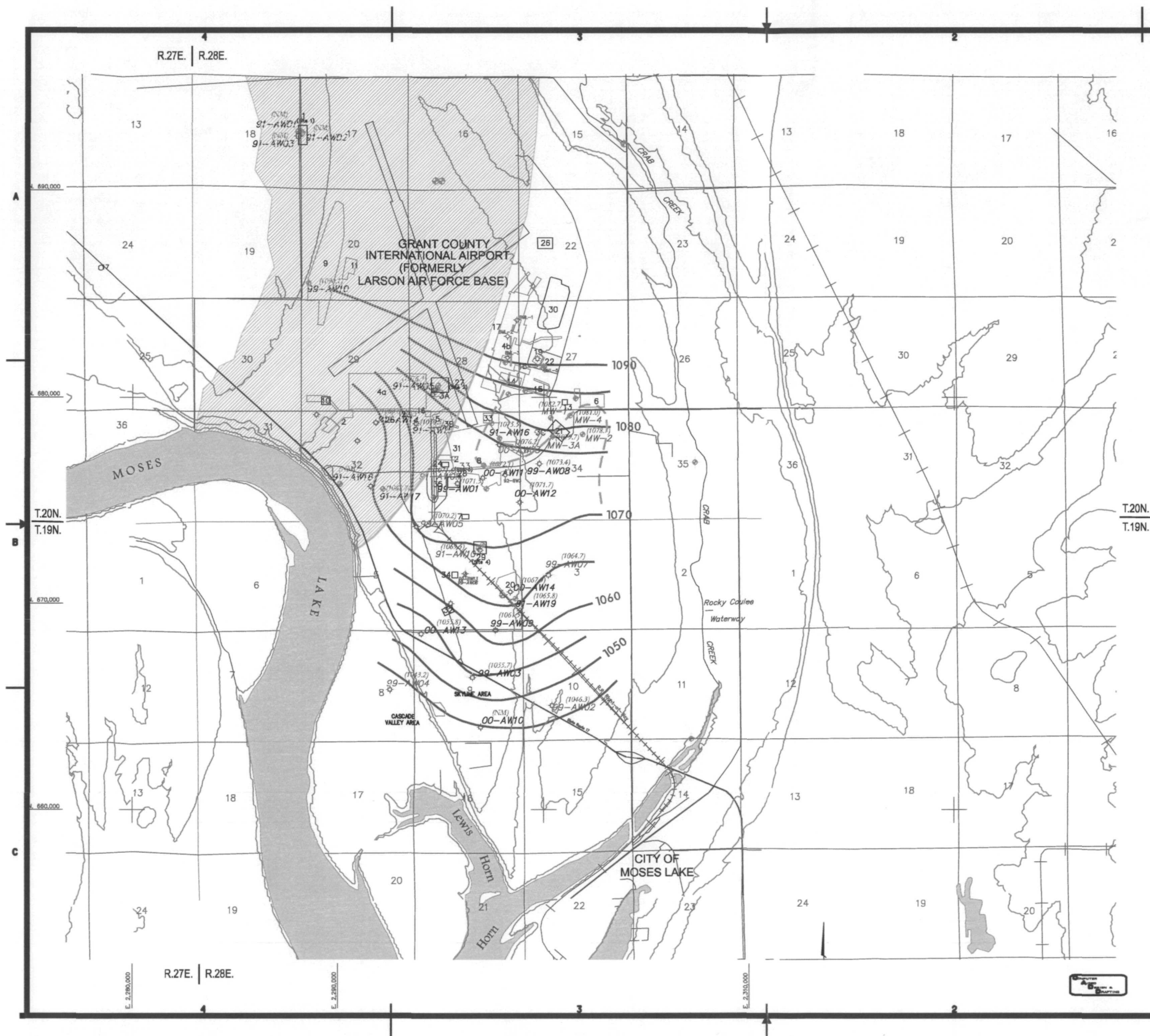
U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

Moses Lake Wellfield Superfund Site
Groundwater Feasibility Study
Geologic Cross Section

Moses Lake D-D' Washington

DATE March 05	FILE NO.	FIGURE 1.4-7
DSCN EBNET	CHK.	SHEET





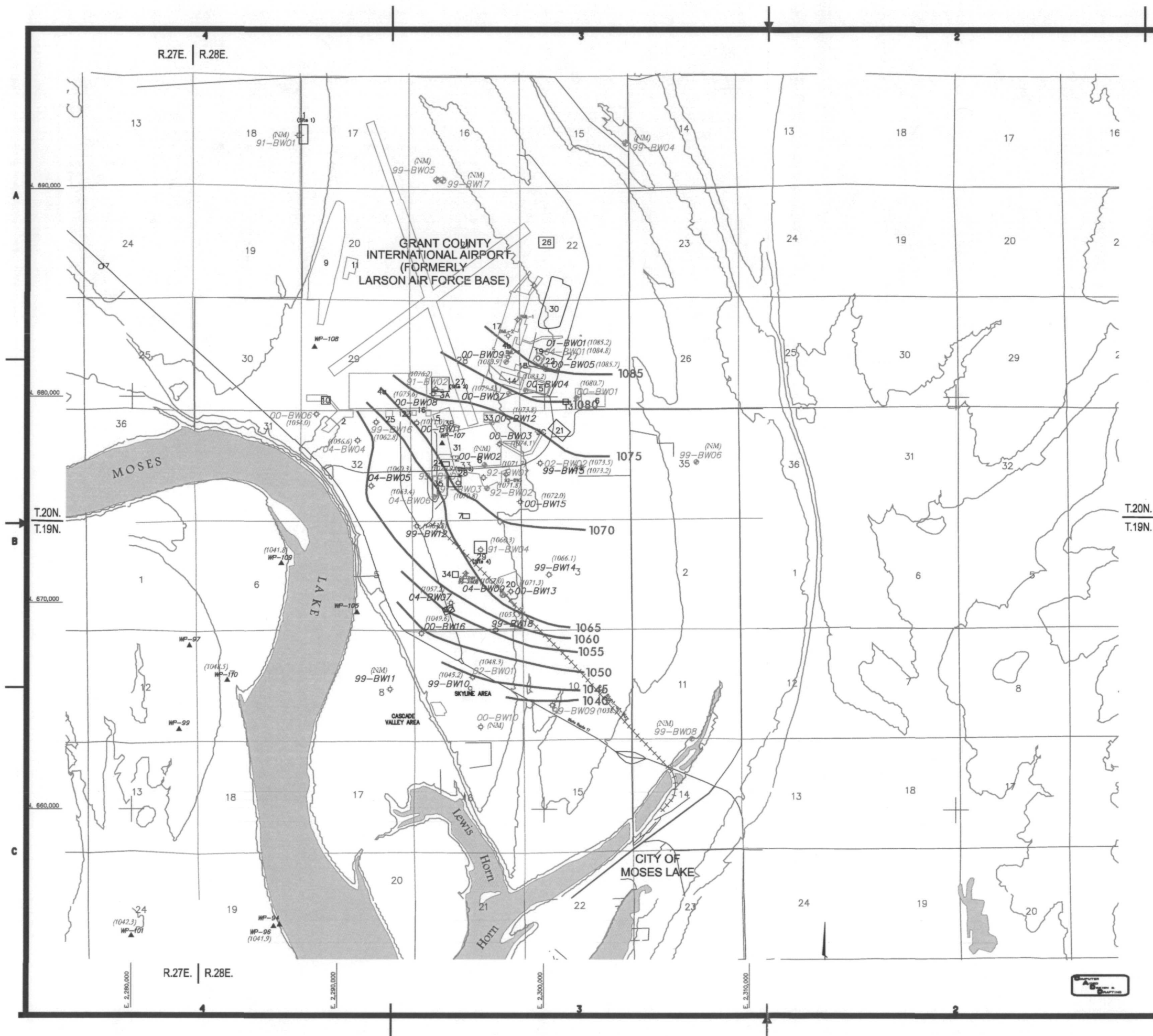
LEGEND

- LOCATION OF GROUPED WELLS
- LOCATION OF SINGLE WELL
- WELL SCREENED IN HANFORD FORMATION
- WELL SCREENED IN RINGOLD FORMATION OR RINGOLD AND HANFORD FORMATION
- GROUNDWATER ELEVATION IN ALLUVIAL WELLS FOR FEBRUARY 2005
- GROUNDWATER ELEVATION NOT MEASURED
- GROUNDWATER CONTOURS FOR FEBRUARY 2005
- APPROXIMATE BOUNDARY OF RINGOLD FORMATION PINCH-OUT
- POTENTIAL SOURCE AREA
- HANFORD FORMATION (UNSATURATED)

NOTES:

1. WATER LEVELS MEASURED ON FEBRUARY 8-9, 2005.
2. ALLUVIUM REFERS TO THE RINGOLD FORMATION AND HANFORD FORMATION.
3. DECOMMISSIONED WELLS: BML-1-5, 99-AW06.
4. WATER LEVELS IN CLUSTERED WELLS WERE REPRESENTED BY ONE OF THE WELLS.

U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON		
MOSES LAKE WELLFIELD SUPERFUND SITE GROUNDWATER FEASIBILITY STUDY		
ALLUVIAL AQUIFER POTENTIOMETRIC SURFACE MAP		
MOSES LAKE	WASHINGTON	
DATE MAR 05	FILE NO.	FIGURE NO. 1.4-9
TECH SWANSON	CHK. GARRISON	SHEET



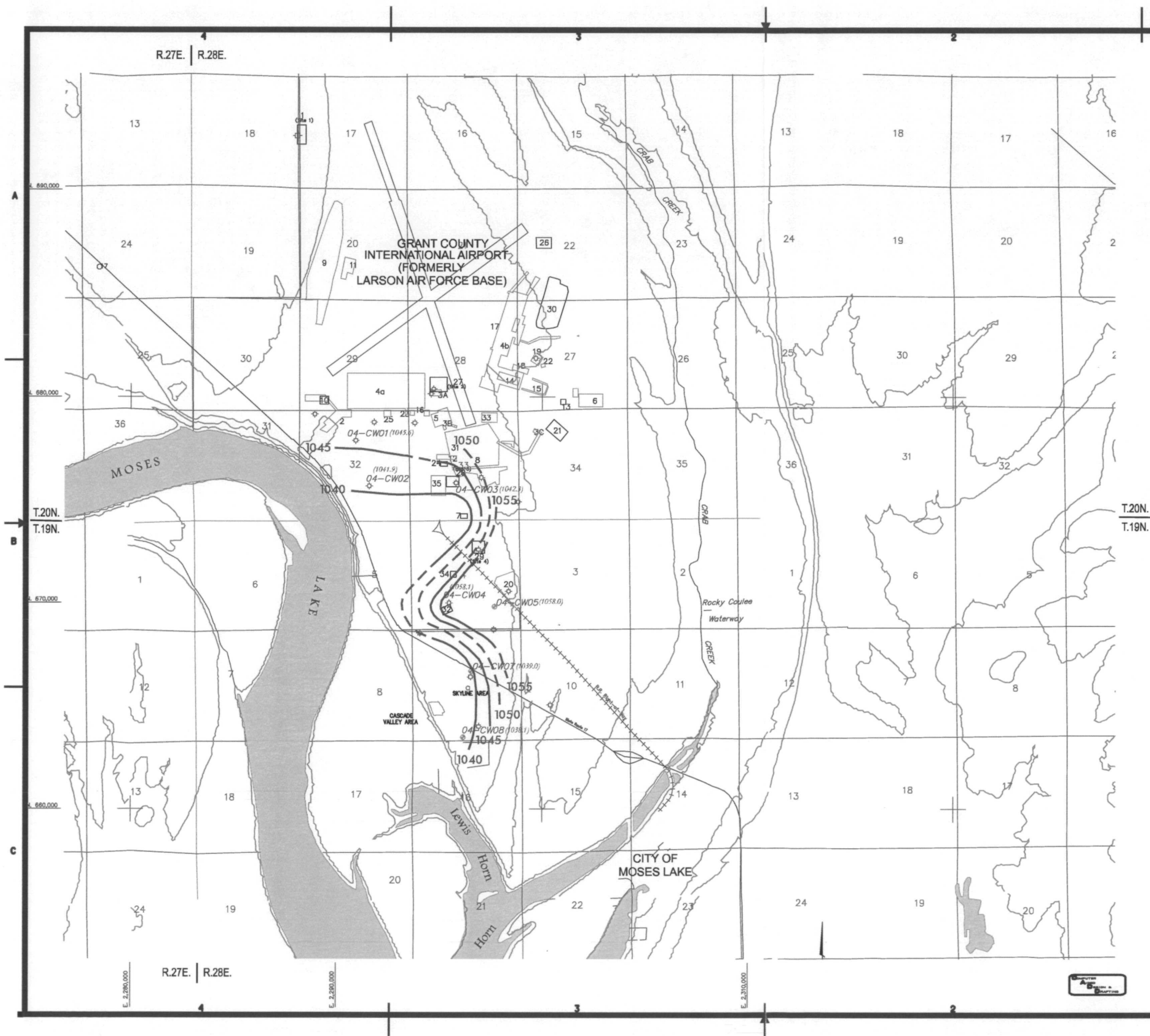
LEGEND

- LOCATION OF GROUPED WELLS
- LOCATION OF SINGLE WELL
- WELL SCREENED IN PRIEST RAPIDS MEMBER
- WELL SCREENED IN PRIEST RAPIDS / ROZA 1 BASALT FLOWS
- WELL SCREENED IN ROZA 1 BASALT FLOW
- GROUNDWATER ELEVATION AS OF 9 FEBRUARY 2005
- GROUNDWATER ELEVATION NOT MEASURED
- GROUNDWATER CONTOURS FOR FEBRUARY 2005
- SAMPLED DOMESTIC WELLS
- POTENTIAL SOURCE AREA

NOTES:

1. WATER LEVELS MEASURED ON FEBRUARY 8-9, 2005.
2. ALLUVIUM REFERS TO THE RINGOLD FORMATION AND HANFORD FORMATION.
3. DECOMMISSIONED WELLS: BML-1-5, 99-AW06.
4. WATER LEVELS IN CLUSTERED WELLS WERE REPRESENTED BY ONE OF THE WELLS.

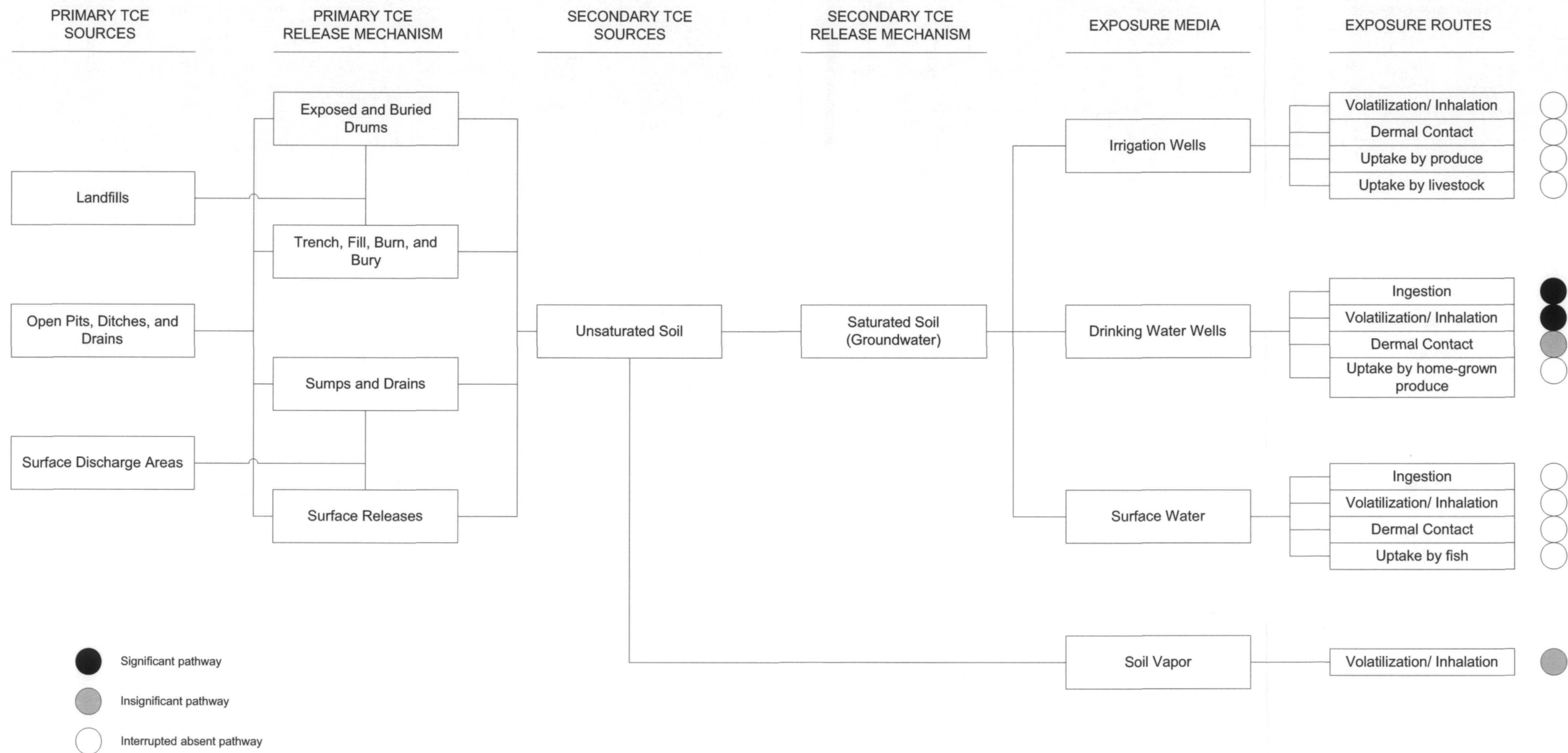
U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON		
MOSES LAKE WELLFIELD SUPERFUND SITE GROUNDWATER FEASIBILITY STUDY		
PRIEST RAPIDS-ROZA1 AQUIFER POTENTIOMETRIC SURFACE MAP		
MOSES LAKE		WASHINGTON
DATE MAR 05	FILE NO.	FIGURE NO. 1.4-10
TECH SWANSON	CHK. GARRISON	SHEET



LEGEND

- ⊕ LOCATION OF GROUPED WELLS
- LOCATION OF SINGLE WELL
- 04-CW08 WELL SCREENED IN ROZA2 BASALT FLOW
- (1041.9) GROUNDWATER ELEVATION AS OF 25 JANUARY TO 2 FEBRUARY 2005
- 1050 GROUNDWATER CONTOURS (DASHED WHERE INFERRED)
- 12 POTENTIAL SOURCE AREA

U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON		
MOSES LAKE WELLFIELD SUPERFUND SITE GROUNDWATER FEASIBILITY STUDY		
ROZA 2 AQUIFER POTENTIOMETRIC SURFACE MAP		
MOSES LAKE		WASHINGTON
DATE	FILE NO.	FIGURE NO.
MAR 05		1.4-11
TECH	OK	SHEET
SWANSON	GARRISON	



1. Methods of Initial Release

Rupture or Leakage
of Drums in Landfills

Concentrated Product Land
Disposal in Pit or Trench

Product Disposal
in Drain

2. First Reservoir: Soil

NAPL

Water Dissolved

Soil Adsorbed

Soil Vapor

3. Methods of Transport in Soil

NAPL* Permeation

Water Dissolved
TCE Permeation

4. Second Reservoir: Groundwater

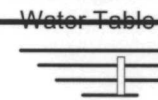
5 Methods of Transport in Aquifer

Gravity Flow

Flow Downstream

NAPL
At Residual Saturation

Downstream Aquifer Layers



To
Groundwater
From
Groundwater

U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

Moses Lake Wellfield Superfund Site
Groundwater Feasibility Study
Conceptual Site Model for Physical Fate and
Transport

Moses Lake

Washington

DATE:
May 05

FILE NO.

FIGURE

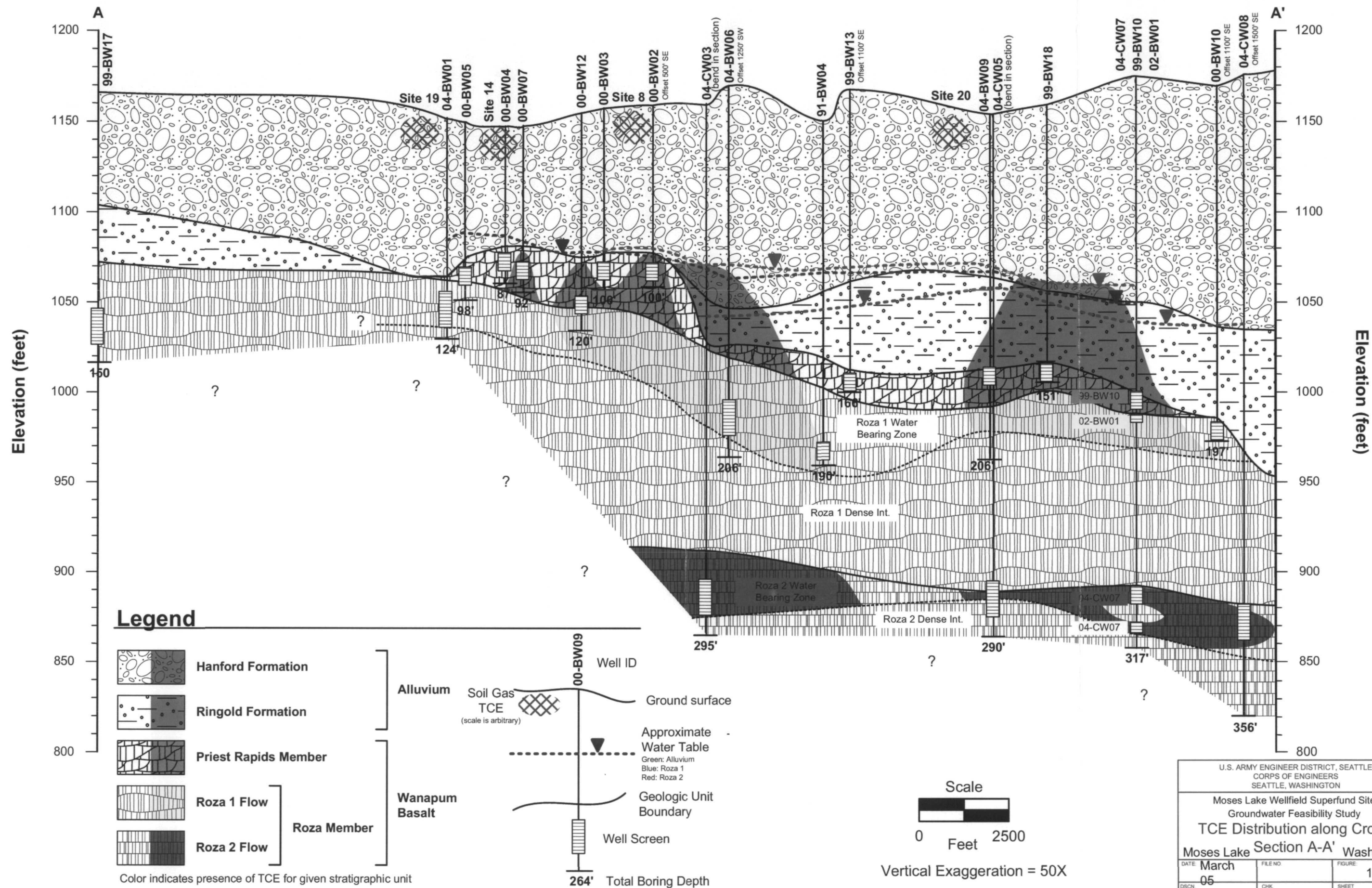
1.5-2

DESIGN

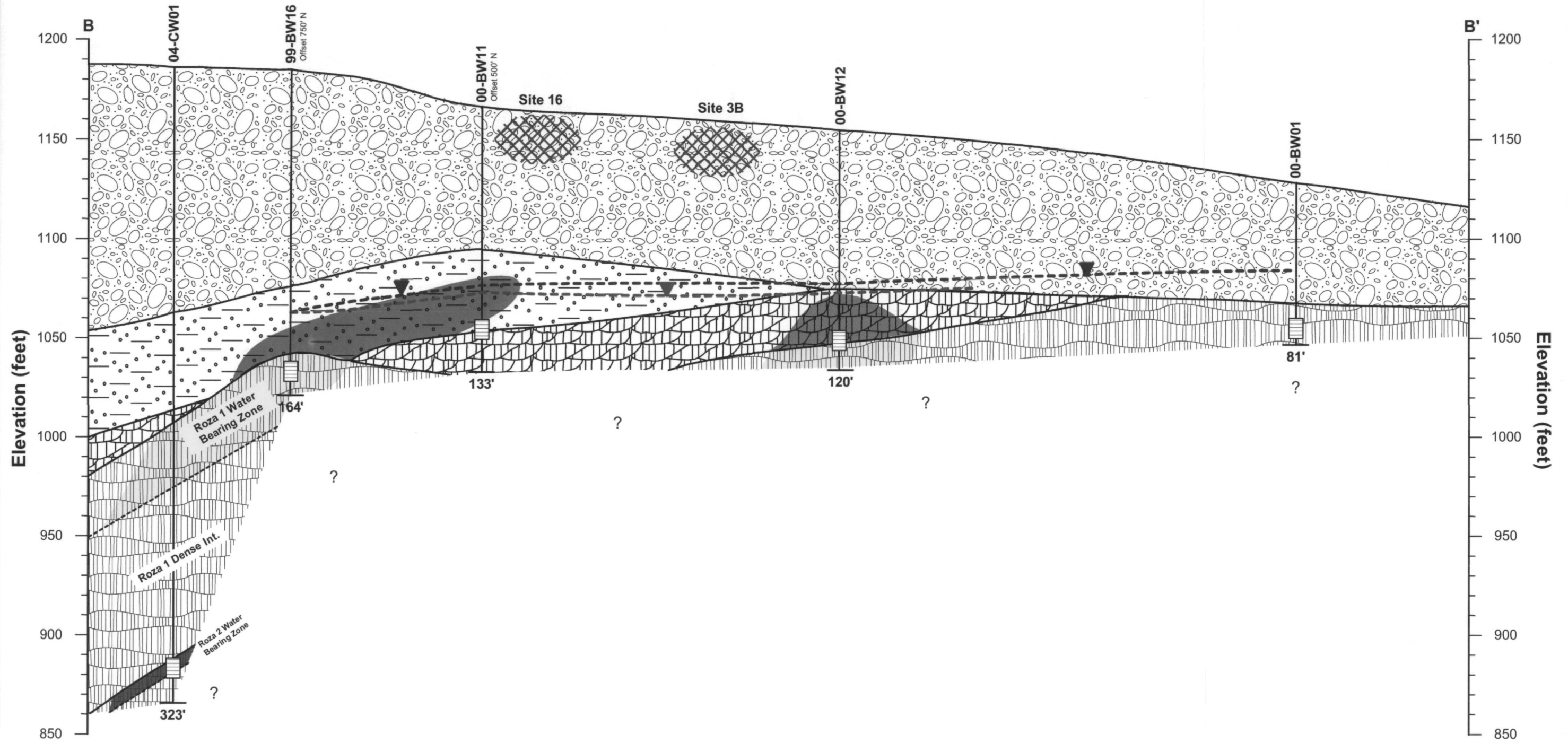
CHK.

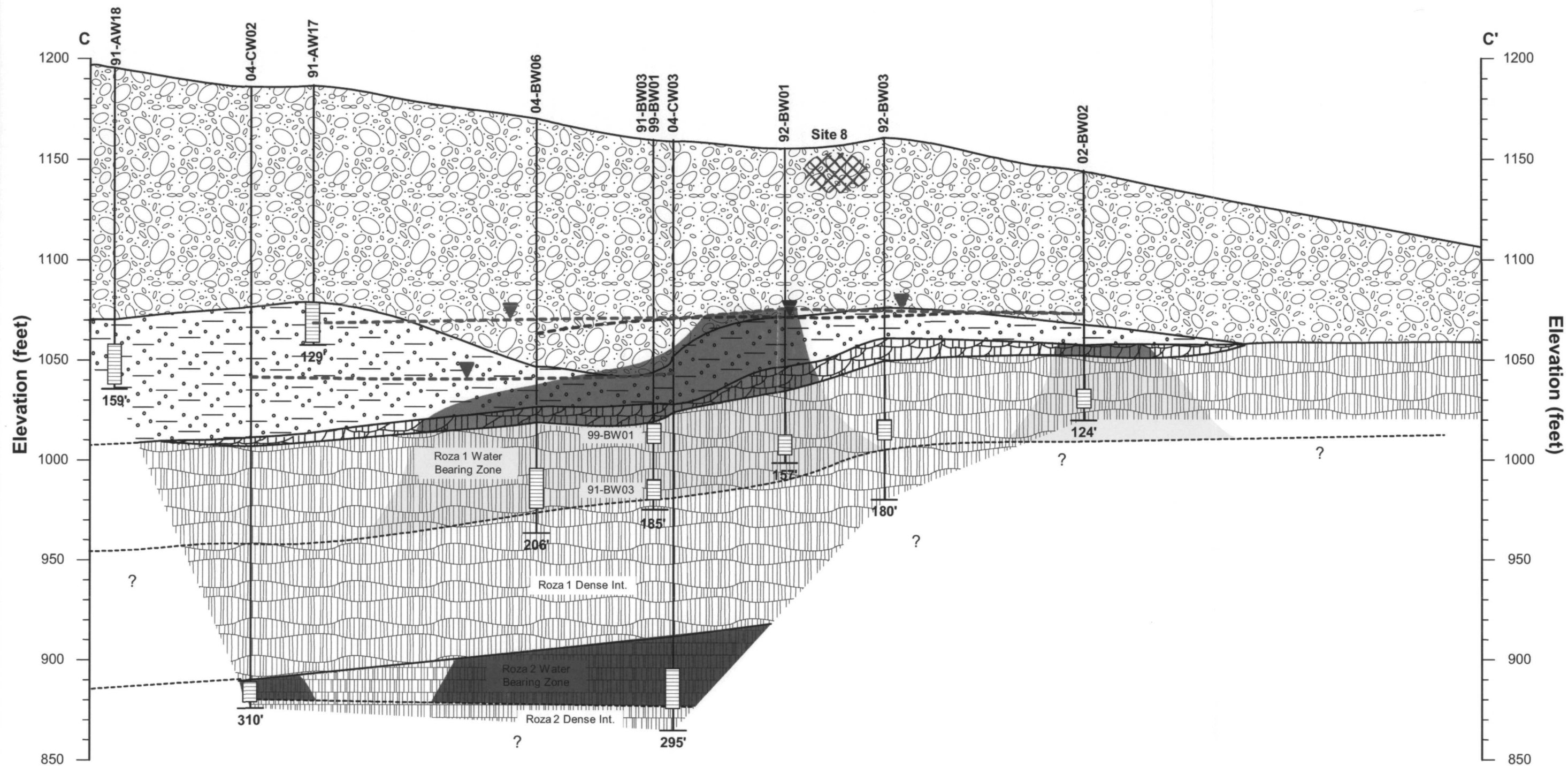
SHEET

WAKEMAN



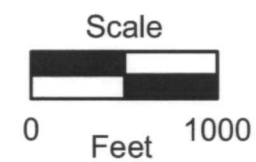
U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON		
Moses Lake Wellfield Superfund Site Groundwater Feasibility Study TCE Distribution along Cross Section A-A' Washington		
DATE: March 05	FILE NO:	FIGURE: 1.5-4
DSCN: EBNET	CHK:	SHEET:





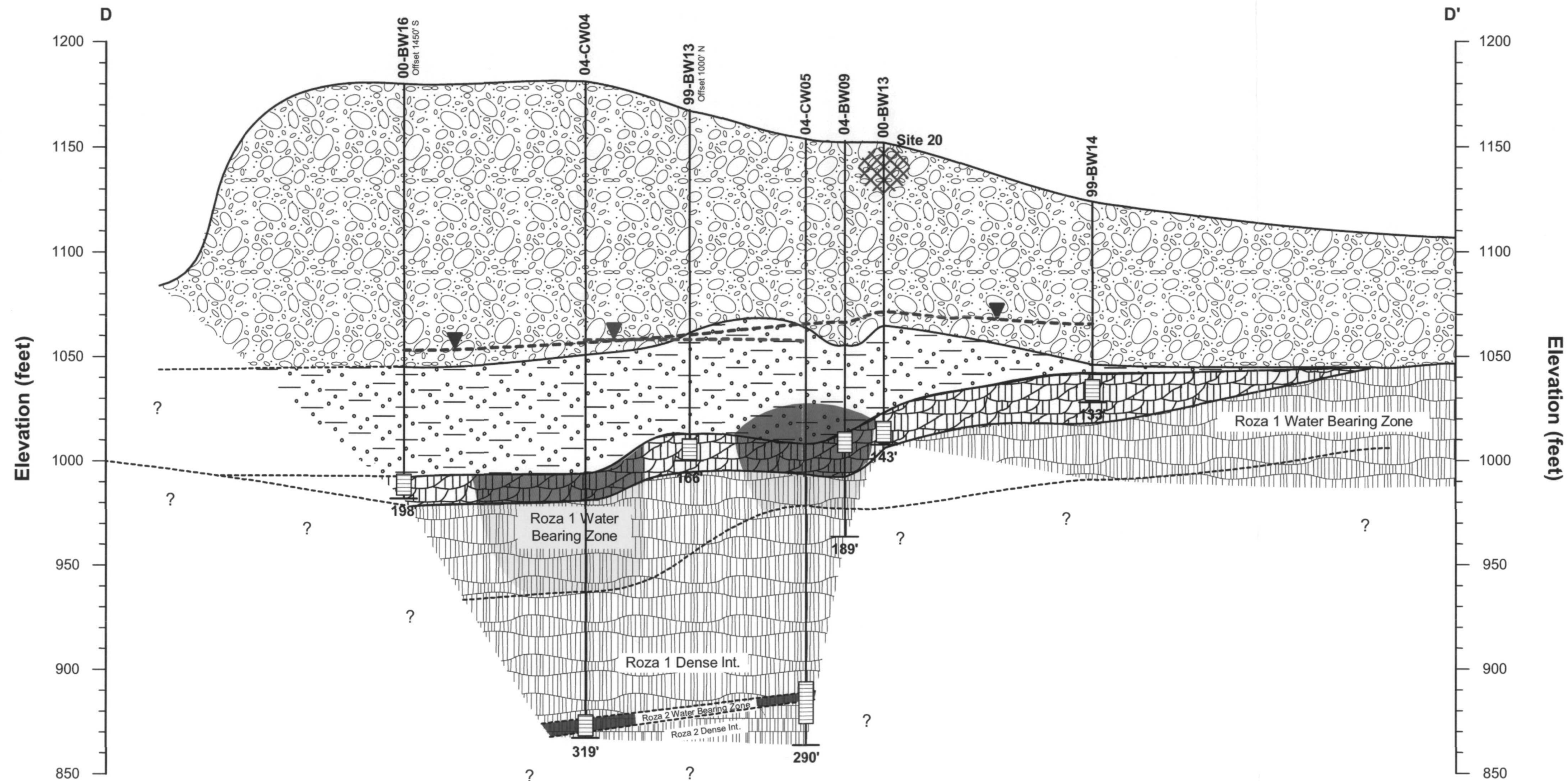
Legend

see Figure 1.5-4



Vertical Exaggeration = 20X

U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON		
Moses Lake Wellfield Superfund Site Groundwater Feasibility Study TCE Distribution along Cross Section C-C' Washington		
DATE March 05	FILE NO.	FIGURE 1.5-6
DSCN EBNET	CHK.	SHEET



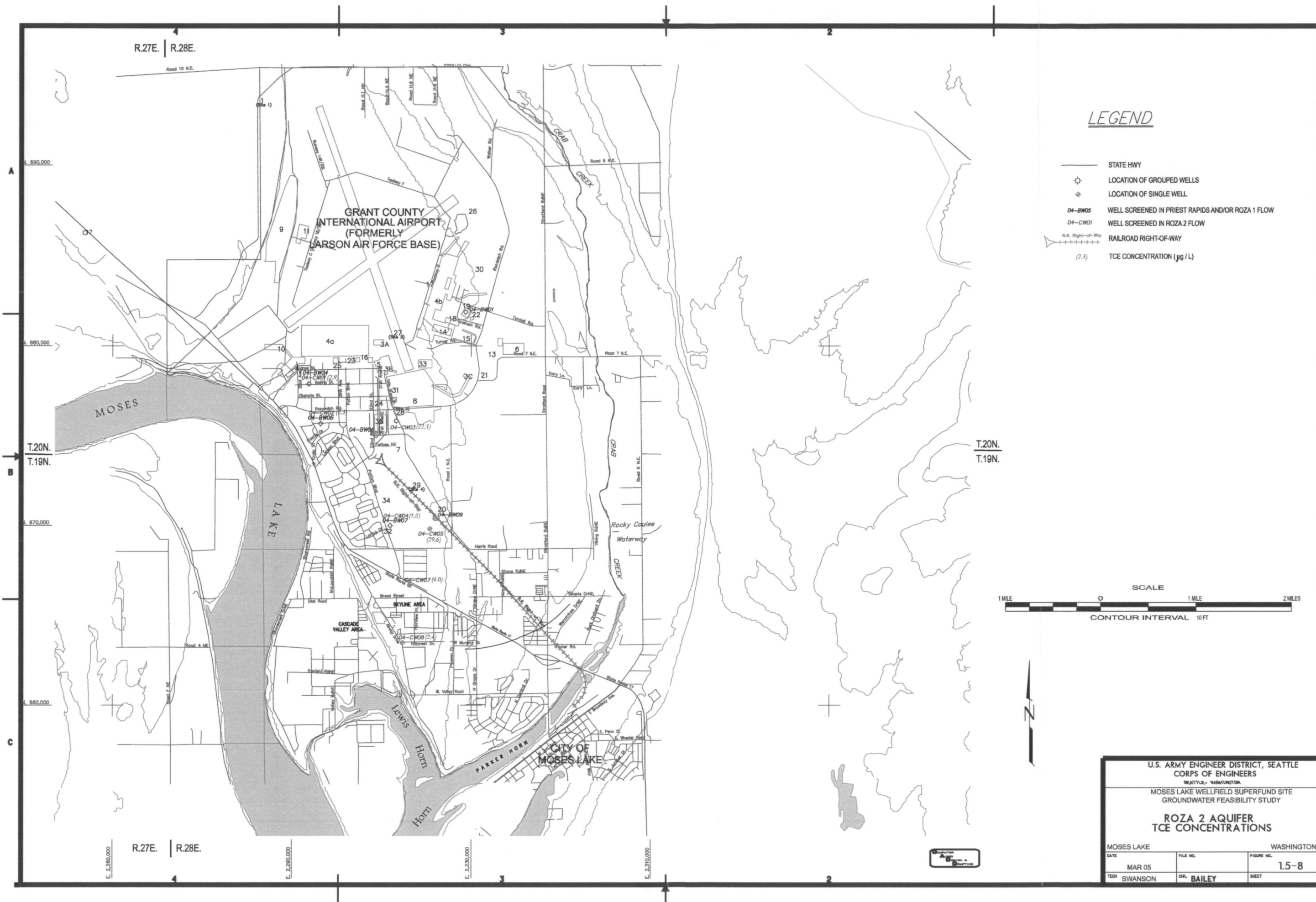
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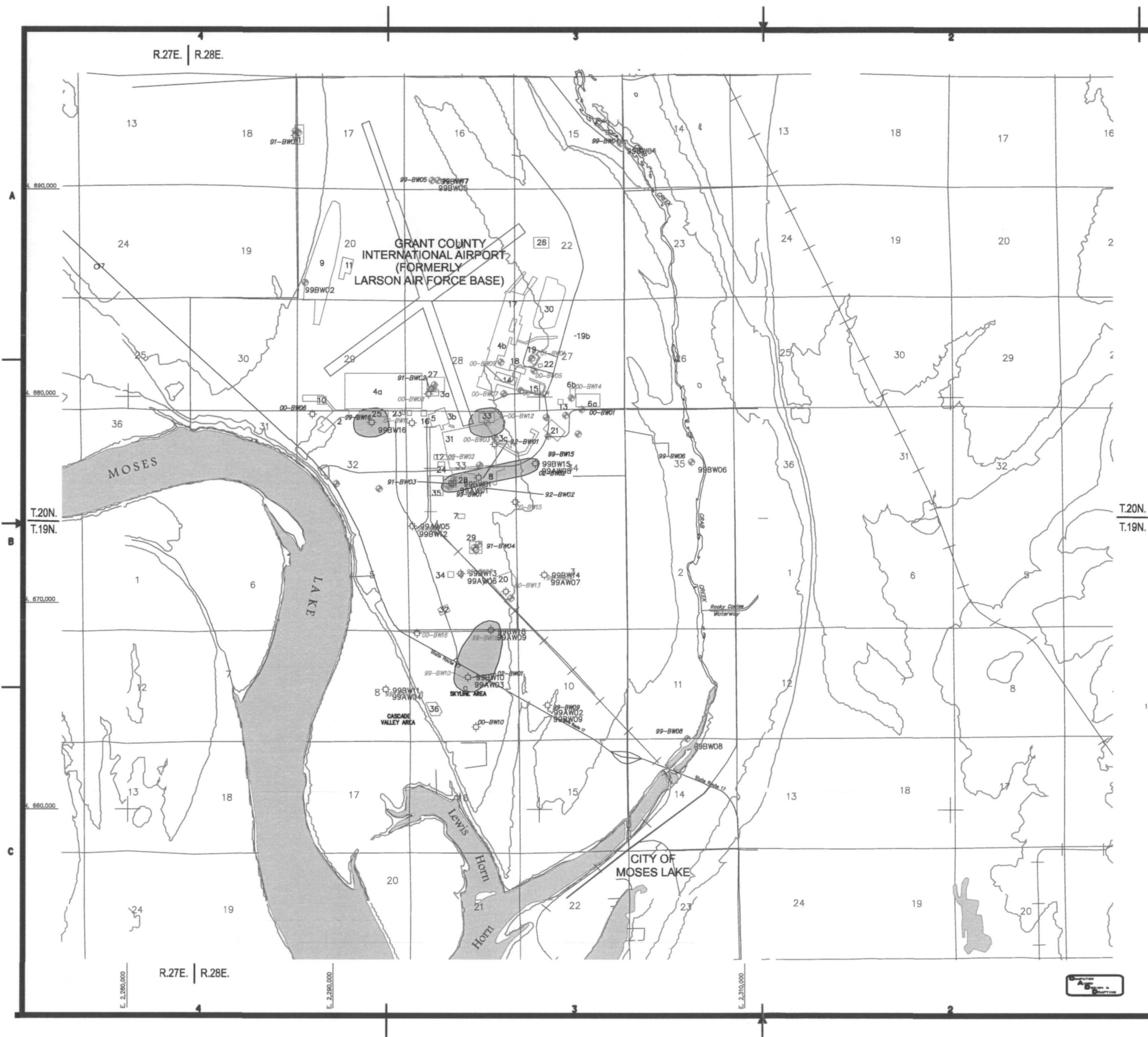
see Figure 1.5-4



Vertical Exaggeration = 20X

U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON		
Moses Lake Wellfield Superfund Site Groundwater Feasibility Study TCE Distribution along Cross Section D-D' Washington		
DATE March 05	FILE NO.	FIGURE 1.5-7
DSCN EBNET	CHK.	SHEET





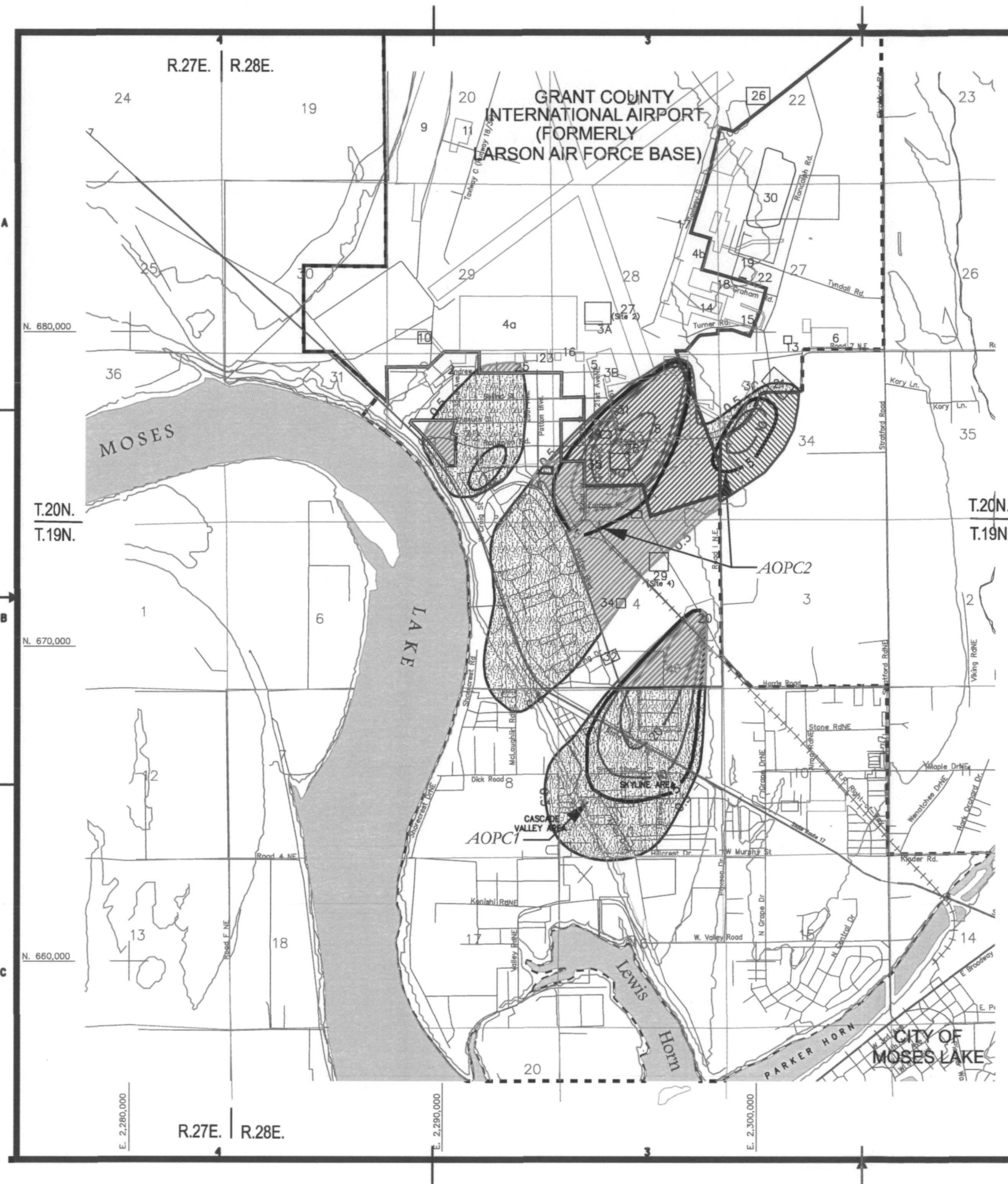
LEGEND

- LOCATION OF GROUPED WELLS
- LOCATION OF SINGLE WELL
- POTENTIAL SOURCE AREA
- POTENTIAL PLUME WITH TCE > 5 µg/L

- NOTE:
- PLUME LIMITS ARE APPROXIMATE AND DO NOT MEAN THAT THERE IS NO CONTAMINATION OUTSIDE OF THE PLUMES.
 - PRE-1999 SAMPLED DOMESTIC WELLS WERE COLLECTED BY DAMES & MOORE, URS GREINER, EPA AND DEPARTMENT OF HEALTH.
 - SEE RI (MWH 2003) AT FIGURE 4-12 FOR INDIVIDUAL WELL CONCENTRATIONS.
 - IN THIS DIAGRAM MOSES LAKE WELLS ML-21, ML-22, ML-23 WERE NOT USED, BECAUSE THEY WERE NOT CLEARLY RELATED TO THIS AQUIFER.



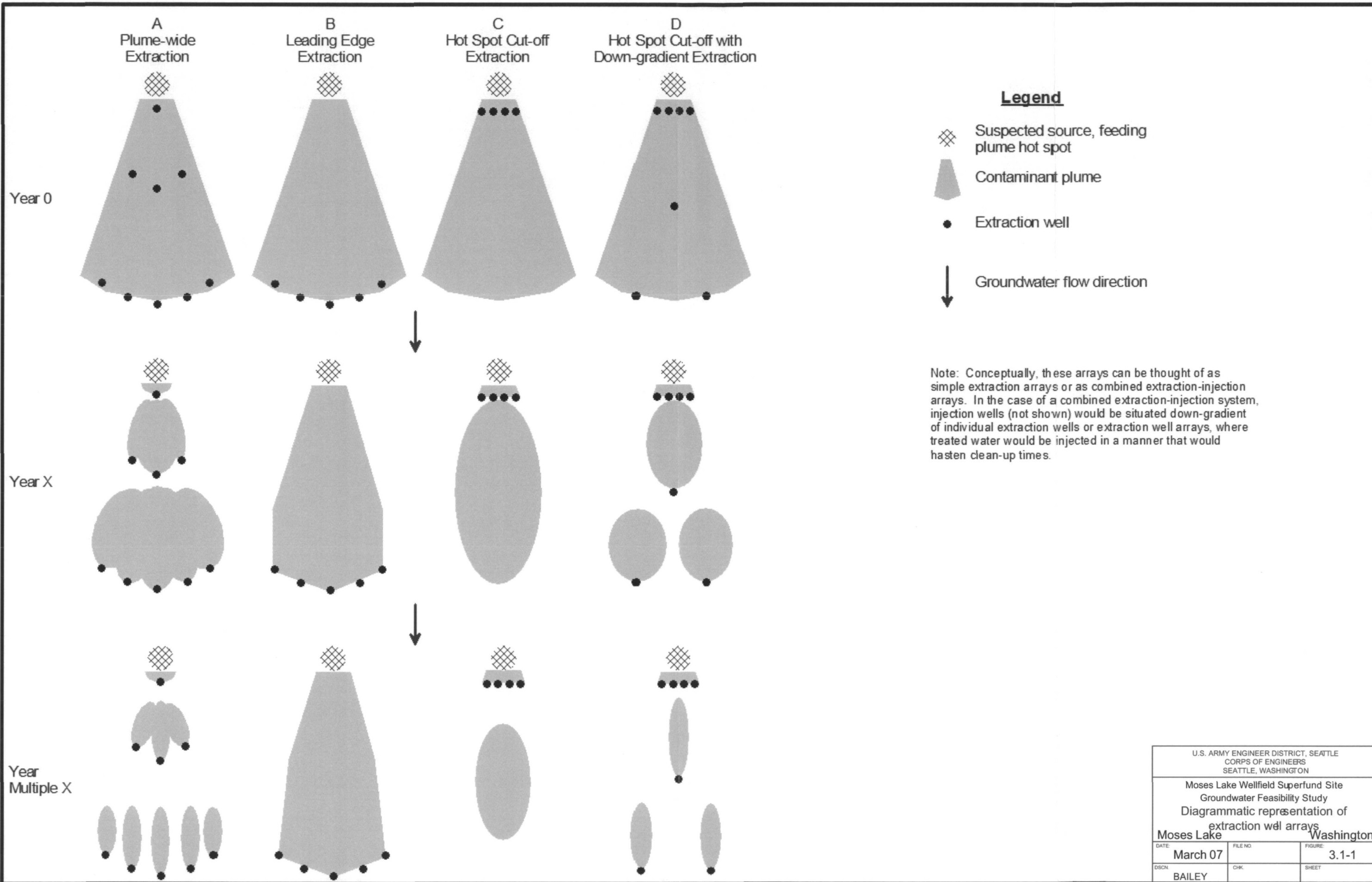
U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON		
MOSES LAKE WELLFIELD SUPERFUND SITE GROUNDWATER FEASIBILITY STUDY		
IDENTIFICATION OF POSSIBLE PLUMES IN ROZA 1 & PRIEST RAPIDS FROM REMEDIAL INVESTIGATION		
MOSES LAKE	WASHINGTON	
DATE MAR 05	FILE NO.	FIGURE NO. 1.6-1
TECH SWANSON	CHK. WAKEMAN	SHEET

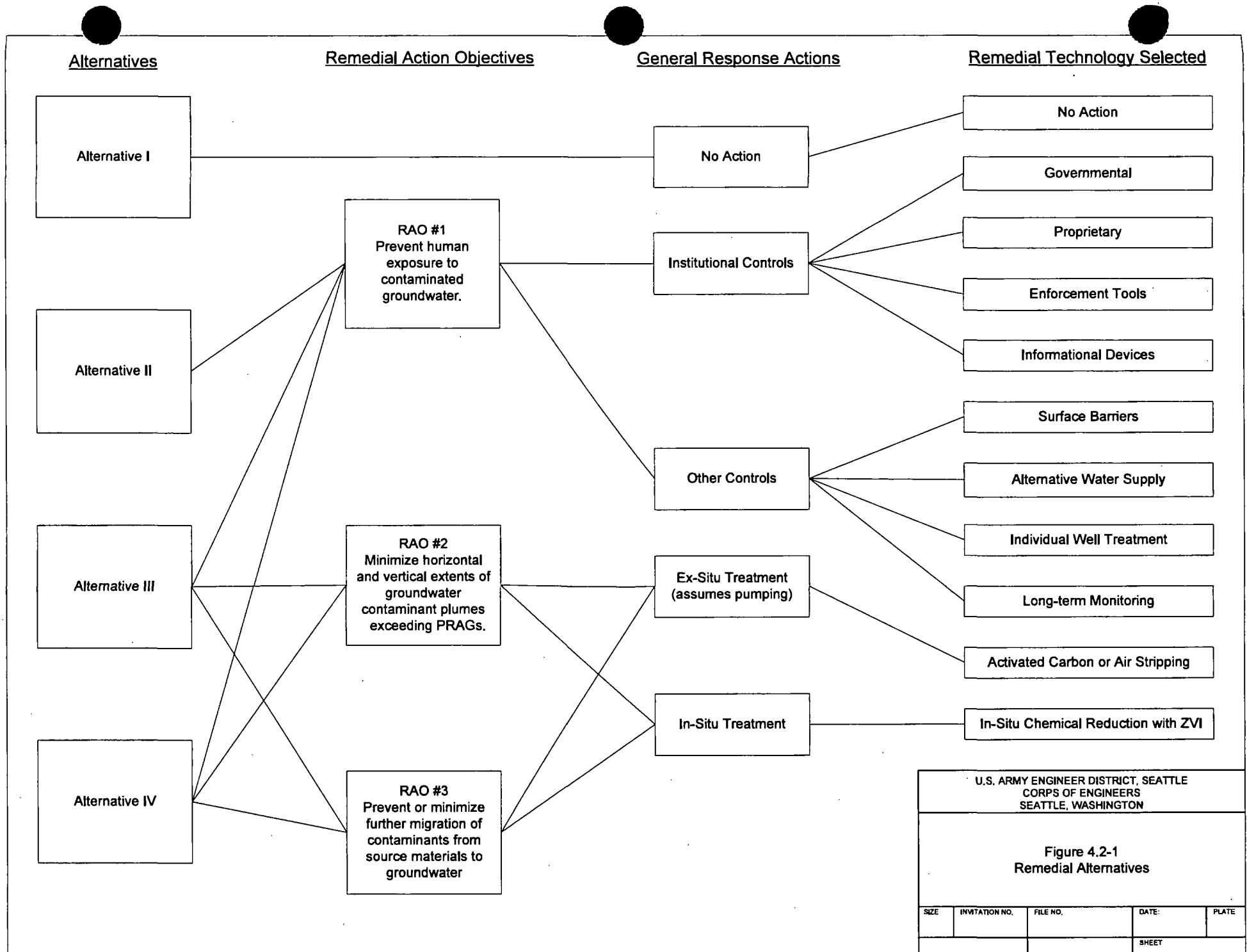


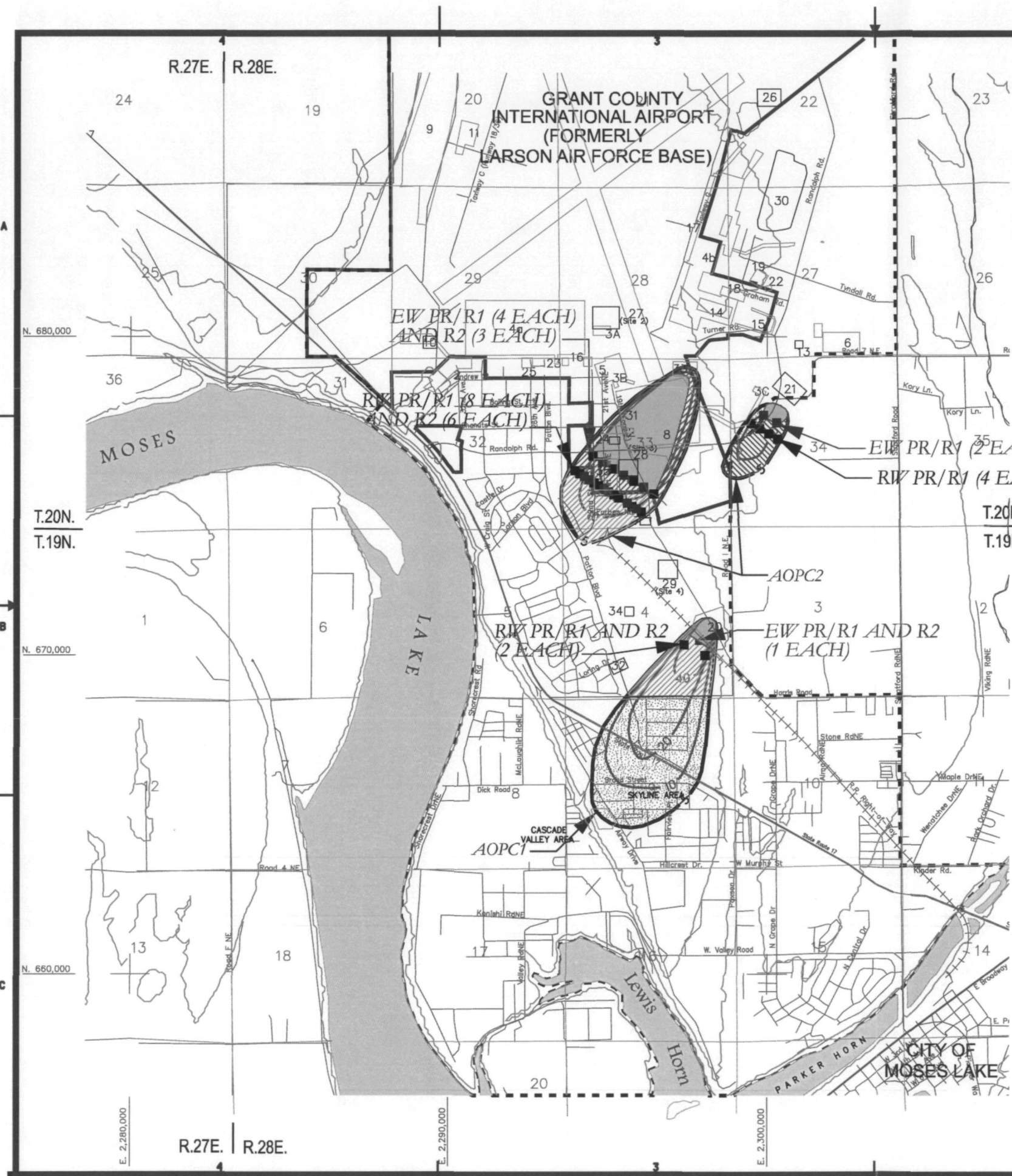
LEGEND

- 12 POTENTIAL SOURCE AREA
- AOPC AREA OF POTENTIAL CONCERN
- URBAN COMMERCIAL/INDUSTRIAL
- URBAN RESIDENTIAL PLUS CITY OF MOSES LAKE
- OUTSIDE URBAN AREA - RURAL RESIDENTIAL
- GRANT COUNTY INTERNATIONAL AIRPORT
- URBAN GROWTH AREA BOUNDARY (LIMITS EXTEND BEYOND BOUNDARY OF AREA SHOWN)
- 0.5 LIMITS OF DETECTION ($\mu\text{g/L}$)
- 5 LIMITS OF AOPC ($\mu\text{g/L}$)

U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS			
SEATTLE, WASHINGTON			
MOSES LAKE WELLFIELD SUPERFUND SITE GROUNDWATER FEASIBILITY STUDY			
AOPC AND DETECTED TCE RELATED TO ZONING CATEGORIES			
MOSES LAKE		WASHINGTON	
DATE	FILE NO.	FIGURE NO.	
MAR 05		2.2-1	
TECH	DR.	SHEET	
SWANSON	WAKEMAN		



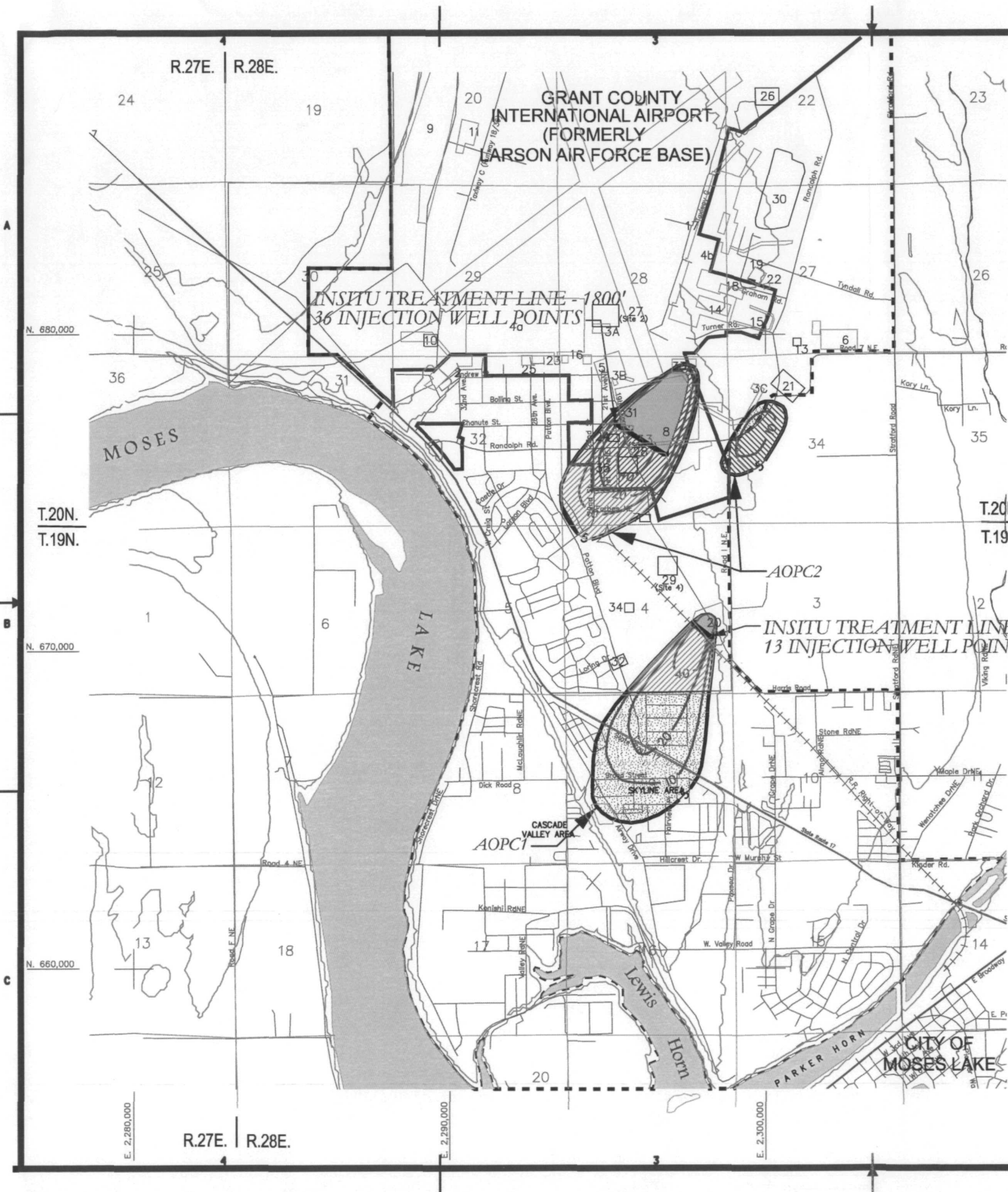




LEGEND

- 12 POTENTIAL SOURCE AREA
- AOPC AREA OF POTENTIAL CONCERN
- URBAN COMMERCIAL/INDUSTRIAL
- URBAN RESIDENTIAL PLUS CITY OF MOSES LAKE
- OUTSIDE URBAN AREA - RURAL RESIDENTIAL
- GRANT COUNTY INTERNATIONAL AIRPORT
- OBJECTIVE STATE FOR PLUME
- URBAN GROWTH AREA BOUNDARY (LIMITS EXTEND BEYOND BOUNDARY OF AREA SHOWN)
- 5 LIMITS OF AOPC (µg/L)
- PR/R1 PRIEST RAPIDS / ROZA 1
- R2 ROZA 2
- RW RE-INJECTION WELL
- EW EXTRACTION WELL

U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON		
MOSES LAKE WELLFIELD SUPERFUND SITE GROUNDWATER FEASIBILITY STUDY		
ALTERNATIVE III WELL LOCATIONS AND OBJECTIVE STATE		
MOSES LAKE	WASHINGTON	
DATE MAR 05	FILE NO.	FIGURE NO. 4.2-2
TECH SWANSON	CHK. MOORE	SHEET



U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON		
MOSES LAKE WELLFIELD SUPERFUND SITE GROUNDWATER FEASIBILITY STUDY		
ALTERNATIVE IV WELL LOCATIONS AND OBJECTIVE STATE		
MOSES LAKE	WASHINGTON	
DATE MAR 05	FILE NO.	FIGURE NO. 4.2-3
TECH SWANSON	CHK. MOORE	SHEET

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION 10

1200 SIXTH AVENUE
SEATTLE, WA 98101

TARGET SHEET

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<u>Groundwater Feasibility Study - Draft Final April 2007</u>	